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ABSTRACT

This publication is developed for grades K-6 as a curriculum guide for the Science/Social Studies Program. The introduction gives purpose and structure of program, format of each unit, sequence of each lesson and key to abbreviated organization or project titles. A map, which orders the units according to grade level and defines the skills, is presented. The major features of the program are: (1) General format for a lesson; (2) Skills and student behaviors; (3) Content; and (4) Evaluation. The content areas are: (1) Physical subsystems; (2) Biological subsystems; and (3) Human subsystems. The units are presented with the same format: (1) Table of Contents; (2) Overview; (3) Materials List; (4) Resources List; (5) Planning; and (6) Lessons. The elements of each lesson are: (1) Objectives or problems; (2) Skills and behaviors; (3) Materials; (4) Content; and (5) Evaluation. Five exemplary units are included: (1) Clay Boats Extended; (2) A Study of Friction; (3) Solutions and Crystals; (4) Weather; and (5) Swing, Sways and Pendulum. (HM)

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1976 SCIENCE/SOCIAL STUDIES R & D

THE SCIENCE/SOCIAL STUDIES PROGRAM of the ACTON PUBLIC SCHOOLS:

I. Scope and Sequence

II. New Units

BEST COPY AVAILABLE

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July, 1976

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INTRODUCTION

The intent of the 1976 Research and Development program for Elementary Science and Social Studies focused on two features of the program, first, the overall structure of the program, the scope and sequence; and second, exemplary units based upon the scope and sequence.

The need for the 1976 Research and Development arose from the desire to have a comprehensive plan which would guide the science and social curriculum. While the major aspects of such a plan existed in its broadest form, it had not been modified by testing or vigorous review until now.

To complement the development of the scope and sequence, teacher writers from the school system both wrote and tested materials with the children of their classes. Some units extend those already in existence but explicitly state skills taught, the content of each lesson to be investigated and the evaluation of each lesson to be done in the form of a colloquium. Others create whole new units to be tried.

In the future we hope to build on this scheme and encourage promising alternative models as counterpoint to the scope and sequence developed here.

Through the efforts of Marilynn Due, Mark Kaufman, Joseph McInerney, Brendon O'Shea as well as Salvatore Lipomi who contributed to the first five sessions we were able to write, test, and modify the activities in classroom setting.

Eugene Trainor, Chairman

THE SCIENCE/SOCIAL STUDIES SCOPE AND SEQUENCE

The Primary Purpose:

To provide an overall system which accounts for the skills and behaviors, Content, and Evaluation, the central learning factors (vectors) of each unit in social studies and science.

To recognize that the social studies and science lesson is the fundamental molecular element to which skill and behaviors, Content, and Evaluation are applied.

To arrange Skills and Behaviors, Content (the units), and Evaluation (discussion - colloquium- after each investigation phase of a lesson) and (a final summative evaluation in the form of a practicum and/or paper and pencil test) in a heirarchy from simple to complex ideas, from kindergarten to sixth grade.

The Overview:

The overview of the scope and sequence begins with the fundamental unit, the interface between teachers and students; between instruction and learning; between curriculum and instruction: THE LESSON. Within each lesson skills and behaviors are identified; the content is defined; and the evaluation is encouraged.

Collectively lessons are placed in units. They are ordered according to complexity of tasks and ideas. The Science and Social Studies R & D for 1976 will follow this format for lesson development.

How does the classroom teacher use the science/social studies scope and sequence? The scope and sequence provides a map which orders the content (the units) according to grade level, but it also defines the skills such as observing, classifying, interpreting data, etc. Under each skill are levels of specific behaviors; i.e., observe the likenesses and differences among natural objects, classifies objects according to one attribute--according to two attributes--describes the meaning of temperature fluctuation in relation to plant growth data.

(continued)

The scope and sequence is used

-- to provide the format for future writings in science and social studies in Boton

-- to provide a sequential path for each lesson to be written

-- to identify skills and behaviors taught in each lesson

-- to provide content in the form of teacher background information and clear procedures in the investigation phase of the unit

-- to assist teacher interpreting the discussion phase of each lesson. In other words, we hope to answer the query "How do we respond to the child when he makes and interprets observations, suggest models and analogies?" Obviously, we will not be able to address all of the questions or interpretations of children, but we hope to examine many of the major ones.

Below find the major features of the scope and sequence:

1.0 general format for a lesson
2.0 skills and attendant behaviors
3.0 content
4.0 evaluation
4.1 formative evaluation, as mechanism for interpreting the statements of children
4.2 summative evaluation

FORMAT OF THE UNIT

Table of Contents

Lists the major features and lessons of the unit

Overview

A statement which sythesizes the unit with the rest of the curriculum

Materials List

The list accounts for the equipment needed, the quanity, and occasionally, the source of a piece of equipment which might be provided by the teacher

Resources List

Books - School Libraries - Acton Town Libraries
A-V - Local, Boston University, Mass. Bd. of Ed.

Planning for Unit (optional)

The efforts and raticnale for the unit might be included here

Lessons

The sequence of lessons, suggested supporting activities, the investigation phase and where possible a colloquium

The Lesson (title)

1.0 Objectives or problems are stated to indicate the focus of the lesson. These may be stated as hypotheses, too.

2.0 Skills and Behaviors
The general skills are stated and the attendant behaviors are arranged below them.

3.0 Materals are listed for the lesson perhaps in the margin

4.0 Content (the investigation phase)

4.1 Background for teacher - Some lessons may require a descriptive statement indicating the implications of the lesson in the total unit if the lesson's intent has not been covered in the unit's introduction.

4.2 Procedure clearly indicated steps for teachers and children to execute

4.21 Children may work from activity cards which may be clustered under one lesson.

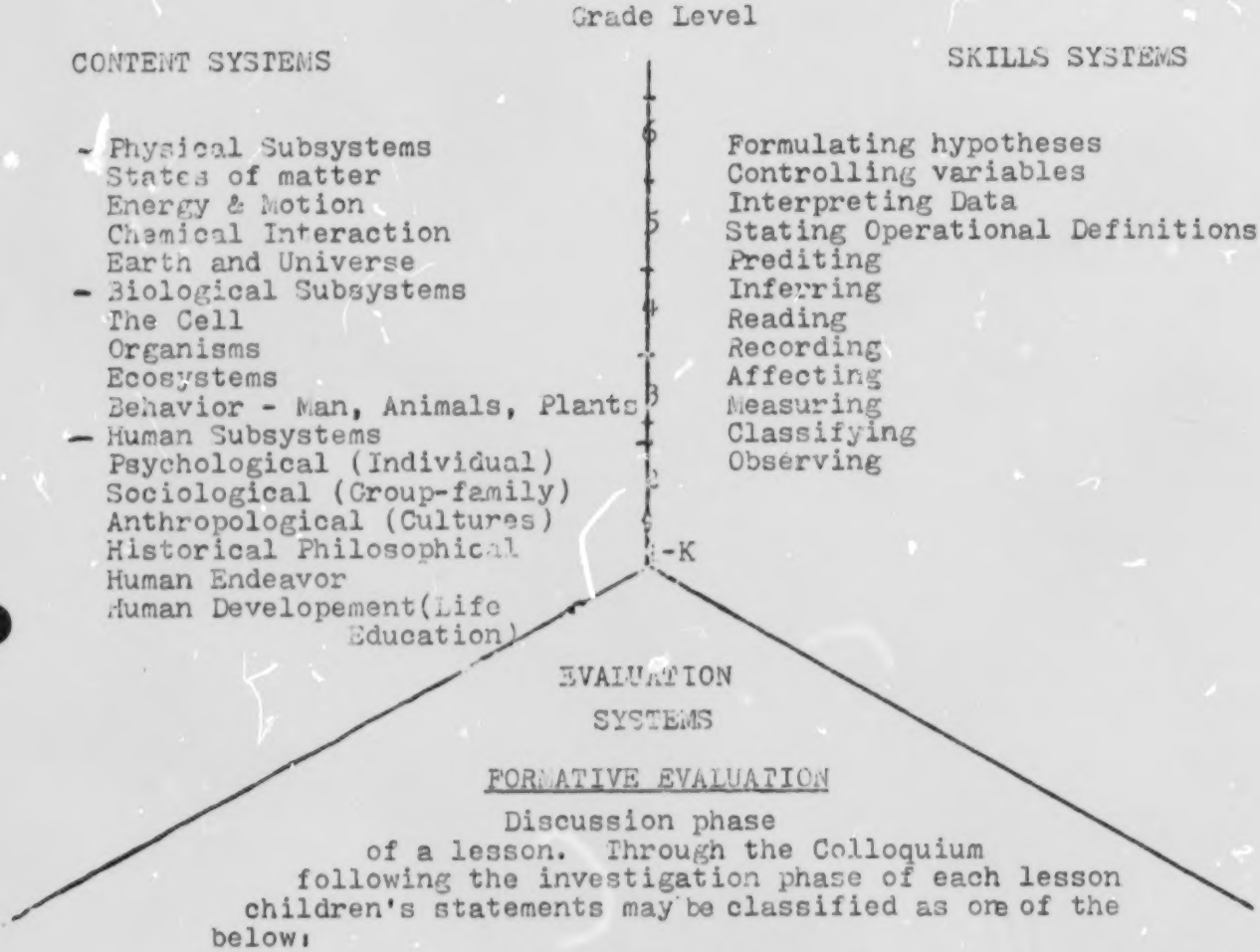
4.22 Data Chart shells may be issued for children to complete.

4.23 Moving in new directions

Tangential activities which extend the basic concept of the lesson will be fostered here

5.0 Evaluation (the colloquium phase)
The colloquium is established to help children refine their own observations and models, to provide a form for children's past experiences through analogies, similies, and metaphors; and, to encourage children to articulate relationships among phenomena on a continuum from simple to complex.

THE STRUCTURE OF THE SCIENCE AND SOCIAL STUDIES
SCOPE AND SEQUENCE



FORMATIVE EVALUATION

Discussion phase of a lesson. Through the Colloquium following the investigation phase of each lesson children's statements may be classified as one of the below:

(1) Perceptual relation-(syncrates) nearness of objects suggests a logical relationship
(2) Concrete specific-relations(complex) external attributes of objects suggest relationship, ie, color, shape texture, function
(3) Abstract - Concrete (Preconcept) Suggest abstractions which are still wedded in the concrete
(4) Abstract relations (concept)- Suggest generalizable relations, possibilities
(5) Analogies - Children use examples from their own past experiences to show relationship to the new experience
(6) Models - Explanations of relationships
(7) Summative Evaluation - Final test

Key To Abbreviated Titles

ESS-------Elementary Science Study: A National Science Foundation program based in Newton, Massachusetts which produced over fifty elementary school science units.

SCIS------Science Curriculum Improvement Study: Another NSF project, based in University of California at Berkley developed a physical and a biological system of units for each grade level.

NSF-------National Science Foundation: A federal government agency granting funds to worthy science projects.

McT-------McCarthy Towne Research and Development Project was devoted to science over two successive summers.

R & D-----Research and Development: A locally funded project organized to produce new curriculum materials. Teacher-writers from the schools develop these materials.

SEE-------Selective Educational Equipment Co., Inc.: A commerical enterprise producing science and social studies kits for elementary schools.

MB--------Match Box: Designate the commercially produced Children's Museum Kits developed under an NSF grant. The children's Museum continues to rent kits which they call Match Boxes but are not available for purchase from school suppliers.

CONTENT SYSTEMS OF UNITS

Physical Subsystems

Grade Level	State of Matter	Energy & Motion	Chemical Interactions	Earth & Universe
K	* Water	* Magnets * Batteries & Bulbs	* Cooking	* Weather
1	*# Clay Boats ¢ Material objects (1978) + Fluids			Nystrom Mapping
2	# Sink or Float	# Primary Balancing ¢ Interaction & Systems * Magnets + Simple Machines		Nystrom Mapping
3	# Mystery powder * Solutions & Crystals ¢ Subsystems & Variables (1977)	* Friction	# Mystery powder + Chemistry	Nystrom Mapping
4	+ Fluids	*# Pendulums ¢ Relative Motion (1978)		* Weather + Earth & Space Nystrom Mapping
5	# Ice Cubes # Gases & Airs	¢ Energy Sources # Batteries & Bulbs + Machines + Light & Lenses	# Gases & Airs	Nystrom Mapping
6	# Kitchen Physics	¢ Models (1977) + Electricity	+ Chemistry	# Daytime astronomy Nystrom Mapping

KEYS: # ESS * R&D ¢ SCIS +McCarthy-Towne

Biological Subsystems

Grade Level	The Cell	Organisms	Communities	Ecosystems	Behavior Man/other animal Plants
K		* Pets * Plants			
1		# Growing Seeds * Seed Dispersal ¢ Organisms-Gates only		+ Outdoors	#Growing Seeds
2		¢ Life Cycles-Gates only + Nutrition			
3		# Eggs & Tadpoles ¢ Populations- Gates only- + Animals	¢ Populations--Gates only + Animals		+Animals
4		+ Pond Study # Crayfish # Bones		+ Pond Study * Grains-Great Plains Unit	+Pond Study #Crayfish
5		# Mealworms			#Mealworms
6	# Small Things	# Small Things + Human Body			+Human Body

KEYS: # ESS * R & D ¢ SCIS + McCarthy-Towne

Human Subsystems

Grade Level	Psychological (Individual)	Sociological Group-Family	Anthropological Cultural	Historical Philosophical
K	* Child's Relation to home	* Community Helpers		
1		SB Families & Their Needs	$ Netsilik Eskimo *$ Hopi Indian *@ Japanese Family	
2		SB Communities & Their Needs	*@ Ashanti Family *@ Japanese Family	
3		*MB City * Colonial Acton *@ Kibbutz	* Acton's 1st. Settlers: Indians	AB Making Our America AB Metropolitan Community
4		AB Industry AB Agriculture		* Great Plains
5			*$ House of Ancient Greece	AB Ancient Civilization AB Medieval Civilization AB 4 World Views AB Greek & Roman
6		@ Russian Family	AB Interaction of Cultures AB New World & Eurasion Cultures AB Challenge of Change	AB Age of Western Expansion

KEYS: * R & D $ Children's Museum @ SEE AB Allyn Bacon SB Silver-Burdett
MB Match Box

Human Subsystems

Grade Level	Human Endeavors	Human Development (Life Education)
K	* Homes	* Child's Relation to Home
1		
2	$ Houses	
3		
4		(LaidLaw) Keeping Healthy
5		(Laidlaw) Growing UP Healthy
6		(Laidlaw) Health For Living

Keys: #Ess * R & D ¢ SCIS + McCarthy-Towne $Children's Museum @ SEE
AB Allyn Bacon SB Silver-Burdett MB Match Box Laidlaw

K - Water; Magnets; Batteries & Bulbs; Cooking; Weather; Plants; R & D (1 year) all

1 Unit	Source	Time	Location
* Clay Boats	* R&D	3wks	All Schools
Fluids - (McT R&D)		4wks	McCarthy-Towne
* Growing Seeds	ESS	6wks	All Schools
Seed Dispersal	Lexington R&D	Manual	
Material Objects	SCIS		Gates (others 1978)
Organisms	SCIS		Gates
Outdoors - McT R&D			McCarthy-Towne

2 Unit	Source	Time	Location
* Sink & Float	ESS	4wks.	All Schools
* Primary Balancing	ESS	4wks	All Schools
* Interaction & Systems	SCIS		All Schools
Magnets	R&D		Avail Manual -Dec.-Jan.-
Simple Machines	McT R&D		McCarthy-Towne
Life Cycle	SCIC		Gates
Nutrition	McT R&D		McCarthy-Towne

3 Unit	Source	Time	Location
* Mystrery Powders	ESS	4wks	All Schools
* Solutions & Crystals	R&D	4-8wks	All Schools
* Eggs & Tadpoles	ESS	Spring	Manual (All)
Chemistry	McT R&D	8Wks	McCarthy-Towne
Subsystems & Variables	SCIS		Gates (All 1977)
Populations	SCIS		Gates
Animals	McT-R&D	4Mo	McCarthy-Towne
* Friction	R&D		All

4 Unit	Source	Time	Location
Weather	R&D	4-6wks	All
Pond Study	McT-R&D	4-6wks	McCarthy-Towne
* Pendulums	R&D - ESS	4-6wks	All
Fluids	McT - R&D	4-6wks	McCarthy-Towne
Relative Motion	SCIS		Gates (All 1978)
Earth & Space	McT - R&D	6wks	McCarthy-Towne
* Crayfish	ESS		Manual
* Bones	ESS		All

5 Units	Source	Time	Location
* Mealworms	ESS	4-6wks	All
* Ice Cubes	ESS		All (Manual)
Gases & Airs	ESS	4-6wks	All
* Energy Sources	SCIS	14-18wks	All
* Batteries & Bulbs	ESS	4-8wks	All
Machines	McT-R&D	3-4wks	McCarthy-Towne
Light & Lenses	McT-R&D		McCarthy-Towne

* Indicates availability early in 1976-77 as major unit

6 Unit	Source	Time	Location
* Kitchen Physics	ESS	8-10wks	All
* Small Things	ESS	6-8wks	All
Daytime Astronomy	ESS	5-7wks	Manual
Models	SCIS	10-12wks	Available(1977)
Chemistry	McT - R&D	6-8wks	McCarthy-Towne
Human Body	McT - R&D	6wks	McCarthy-Towne
Electricity	McT - R&D	8wks	McCarthy-Towne

* Indicates availability early in 1976-77 as major unit

PROGRAM OVERVIEW -- SOCIAL STUDIES

K - Child's Relation to Home — R & D — All
Community Helpers

1 - Text: Families and Their Needs
Study Prints: "The Earth, Home of People"
Kits: "Hopi Indian Kit" — SEE — All
"Hopi Indians" — Mini Matchbox
"Netsilik Eskimos" — Matchbox. Children's Museum
"Algonquin Indian" — Mini Matchbox.

2 - Text: "Communities and Their Needs" Silver Burdett — All
Study Prints: one of each country per school
"Living In Brazil"
"Living In France
"Living In Japan; Kenya; Soviet Union; United States; Mexico"
Kits: "Ashanti Family of Ghana" — SEE — All
"Houses" — Matchbox Unit
Children's Museum

3 - Text: "Transition Year From Silver Burdett's People Use the Earth" to The Making of Our America and The Metropolitan Community
Study Prints: "United Nations Day" "Brotherhood Week" — All
Kits: "City" — Matchbox — All but McT
"Kibbutz Family in Israel"
Green Circle Demonstration

4 - Texts: Agriculture: "Man and the Land"
Industry: "Man and the Machine"
Study Prints: Available
Kit: Great Plains Kit: Grasses and Grains, Indians, Cowboys, Farming
Unit: "Massachusetts" - available for each teacher

5 - Texts: Allyn & Bacon - Ancient Civilizations; Medieval Civilizations; Four World Views; Greek & Roman Civilization
Study Prints: "See Grade 4"
The system owns four "House Of Ancient Greece" Kits (MATCH) housed in Conant, Douglas, Gates, and Merriam Schools
Matchbox Units: "Medieval People"

6 - Texts: Allyn & Bacon - The Age of Western Expansion; New World and Eurasian Culture; The Challenge of Change; The Interaction of Cultures
Study Prints: "See Grade 4"
Conant, Douglas, Gates and Merriam Schools each own a "Soviet Family in Moscow" Kit (SEE)
Each school has "Man: A Cross Cultural Approach"

Grade 1 Science Units - annotated listing

==== Unit Name	Source	Time
1. Clay boats	R&D, ESS	3wks

Clay boats - observing the conservation of volume of water, sand, and peas. Observing, classifying and hypothesying about the floatation and the sinking qualities of various materials.

2. Fluids	McT - R&D	4wks

Fluids - properities of air and water using observation of various phenomena.

3. Seed dispersal	Lexington R&D	Manual

Seed dispersal - what is a seed and what is a fruit. Classifying of seeds and fruits. Observing the various methods of seed travel, air, water, animals and parent plants.

4. Material objects	SCIS	Gates (others 12wks 1987)

Material objects - Classifying of objects in relation to one or more attributes (size, color, etc.) serial ordering, change evidence, etc.).

5. Outdoors	McT - R&D	8-10wks

Outdoors - Observation of outdoor phenomena. Classifying specific trees, leaves, seeds, small communities, fields, etc.

6. Organisms	SCIS	10-12wks

Organisms - Children observe some of the requirements for life as set out seeds and watch the plants grow. They observe and discuss birth of guppies, snail egg growth of guppies, and snails death of organisms

Grade 2 Science Units - annotated listing

====Unit Name	Source	Time

Sink or Float — ESS — 4-6wks

This unit is a follow up to clay boats which was done in the first grade. It "offers children experiences with a variety of solids and liquids, with displacement of volumes of water, and with bouyancy." It also offers an initial exposure to density.

Primary Balancing — ESS — 4-8wks

This unit presents a wide range of activities that introduce balance and weight. Children use a variety of materials to explore and solve problems and to generate understanding of some of the physical principles of balance.

Interaction and Systems — SCIS — 12-18wks

Uses mechanical and electrical systems and observes the relationships within and between these systems.
This is being introduced to the system in the fall of 1976. Workshops will be scheduled for teachers during the fall.

Magnets — Lexington, Mass. R&D — 3-4wks

Children devise systems for measuring the strength and weakness of magnets.
This unit is in preparation by Gene Trainor and will be available through him in December.

Simple Machines — R&D - McT — 4-8wks

Explores motion and simple machines, lever, pulley, screw, inclined plane. Can be made available to any teachers in the system.

Life Cycles — SCIS — Approx. 6wks

Examines the growth, development and life cycle of various plants & animals. Primarily an observational unit.

Nutrition — McT - R&D — 6-8wks

This is an examination of the nutritional aspects of different foods, involving studying, preparing and eating various foods, analysis of the basic food categories, examination of content of processed foods.

Grade 3 Science Units - annotated listing

Unit Name	Source	Time
Mystery Powders	ESS	4wks

Mystery powders: An introduction to the characteristics of familiar powders. Children investigate and perform experiments to determine the properties of these powders.

Solutions & Crystals	'76 R&D	4-8wks

Solutions and crystals: Follow-up to "Mystery Powders." Children experimentally determine the properties of various solutions. and they grow crystals in the classroom.

Eggs & Tadpoles	ESS	

Eggs and Tadpoles: Children observe the development of frog eggs. This is basically an observational unit and should be done in the spring. See Gene Trainor for further details.

Chemistry	McT - R&D	8wks

Chemistry: An overview of experiments and recommendations covering mystery powders and solutions ("Elementary Exploration in Chemistry"), the ESS unit "Heating and Cooling," and chemical analysis of various materials ("Chemistry of Familiar Things").

Subsystems & Variables	SCIS	Gates presently, all by 1977 8-12wks

Subsystems and Variables: A continuation of previous SCIS physical science units. The children explore electrical circuitry, powders and solutions, temperature changes in systems, and elementary machines. Note: the sifting experiments with powders do not work successfully and need revision, as of 7/76

Populations	SCIS	10-15wks

Populations: A continuation of previous SCIS biology units. The children set up communities of land organisms (plants, sphids, crickets, chameleons) and aquatic organisms (algae, snails, damselflies, and daphnia), and observations are made of the relationships within each community.

Animals	McT - R&D	4mo.

Animals: A structural and categorical analysis of animal life. Animals are classified by appearance, tools, and behavior. This is basically an observational unit.

Friction	'76 R&D	3-4wks

Friction: The children experiement with factors that influence friction between various surfacrs, ways of reducing friction, and ways in which friction is useful to man.

Grade 4 Science Units - annotated listing

***=Unit Name	Source	Time
Weather	R&D	4-6wks

Weather: A look at the various forces that affect weather: air pressure, wind direction and flow, humidity and temperature. Much of the focus will be on local, out of classroom experimentation and observation; however some demonstration lessons will examine the larger examples of weather phenomena such as rain, snow, tornadoes, etc. Recording

Pond Study	McT	4-6wks

Pond Study: A 4-6 week study that is part of the McT "Nature" R&D. This is a fair weather unit looking at the overall ecology of a fresh water environment with special focus on microscopic life.

Pendulums	R&D ESS	4-6wks

Pendulums: A look at harmonic motion and all the factors that influence the round trips of pendulums. Various type pendulums will be constructed from simple materials provided by the kit and common scrounge sources.

Fluids	McT	4-6wks

Fluids: The focus in this unit will be on the physical qualities of air and liquid fluids and the unique laws that govern their interactions. Numerous experiments and activities are included.

Relative Motion	SCIS	Gates(all 1978)

Relative Motion: Working with Mr. O, who views the world only from his own perspective, children are asked to take him on trips and comprehend how he see changes in his motion, A look at real, apparent and relative motions.

Earth & Space	McT	6wks

Earth & Space: The areas included concern an exploration of relative motions and directions on the earth and our perceptions of the larger iniverse. There is a section on the formation of the earth and basic geological principles that could be pursued as a seperate unit of study.

Crayfish	ESS	

Crayfish: Observing the behavior of crayfish. In small plastic pools children can observe how crayfish live, defend their homes, mate and reproduce themselves. It is also easy to observe the detailed anatomy of a single crayfish.

Grade 5 Science Units - annotated listing

Unit Name	Source	Time
Energy Sources	SCIS	14-18wks

Energy Sources: Children explore physical and chemical sources of energy. They measure forces and momentum, and devise experiments to measure these factors. Exciting experiments tracking movement of spheres using electric motors and making batteries.

Batteries & Bulbs	ESS	4-8wks

Batteries & Bulbs: A unit used by many Acton teachers. Children utilize such variables as seven types of wires, 2 types of bulbs and varying number of batteries. Children also experiment with magnets and compasses. Observing, inferring, using numbers.

Machines	McT

Machines: Studying and manipulating simple and complex machines are coupled with the basic ideas of friction, momentum, and motion.

Light & Lenses	McT - R&D	3-4wks

Light & Lenses: Can be combined with Optics
Children focus light beams through lenses as well as observing the phenomena of refaction, reflection, color and polorization.

Mealworms	ESS - Kit	4-6wks

Mealworms: In the mealworms' unit children create experiments with the larva stage of the meal Beetle. They observe movement and reaction to heat, vinegar, salt, sugar, and other common items. Children follow the movements of the animal in a maze and on the surfaces of the box. Skills, observing, graphing, recording, predicting.

Ice Cubes	ESS

Ice Cubes: Children study the physical properties of ice, its melting rate and the rate at which different objects melt through the cubes - an interesting unit involving graphing of temperature, observing drip rate, and weighting differences in water and ice. Observing, recording, predicting.

Gases & Airs	ESS	4-6wks

Gases & Airs: This unit expands upon the experiment where a lighted candle in a saucer of water is covered by a jar. Variations include the amount of water up-take in an enclosed container of geminating seeds, steel wool, as well as the candle experiment. Observing, measuring, formulating hypothesis, interpreting data.

Grade 6 Science Units - annotated listing

====Unit Name	Source	Time

Kitchen Physics — ESS — 8-10wks

Kitchen Physics: Extensive sets of experiments with liquids are developed in this unit. It provides a direct experience with the adhesion of liquids and solid surfaces, heaping of water, the beading effect of water, the absorption and evaporation of different liquids --- controling variables, measurement, classification, stating hypothesis, influence and prediction.

Small Things — ESS — 6-8wks

Small Things: With microscopes as their principal instrument children explore the behavior of microorganisms and examine onion cells, salt, sugar, as well as other objects of interest. Children learn basic microscopy technique using microscopes, mounting slides, using coverslips and staining specimens.

Daytime Astronomy — ESS — 5-7wks — Maual (all)

Daytime Astronomy: The movement of the moon and sun over several months is thd focus of this unit. Children follow shadows and light beams during a day and at given hours during several weeks. Predicting recording measuring, stating hypothesis.

Models: Electric & Magnetic Interactions — SCIS — 10-12wks — 1977

Models: Electric and Magnetic Interactions - Children work with light bulbs, batteries, magnets, and compasses. The concept of model is introduced when children investigate electric puzzles and mystery boxes. The concept of model is first applied in the understanding of magnetic field encourages children to manipulate magnets and coils of wire attached to batteries to determine their force. This unit extends Batteries and Bulbs.

Chemistry — McT - R&D — 6-8wks

Chemistry: Children work with acids and gases. They learn in the course of this unit the relation of these substances to digestion of food, production of light, batteries, and disolving objects. Observing, measuring, recording, inferring, predicting.

Human Body — R&D — 6wks(1976-77)

Human Body: This unit examines body organs and systems. Helps children test the function and structure of various systems of the body.

Electricity — McT - R&D — 8wks

Electricity: The technical interactions discovered in batteries, bulbs and wire coils cannot help but draw children toward conceptual explanations not observable here. These concepts are buried in hypothesis and models explained in the past.

Grade 1 Social Studies - annotated listing

Texts: Silver Burdett Families and Their Needs---Studies of of Families of Eskimos, of Japan and of New York City; Shelter and houses; food and clothing are examined. A section on the United States is included.

Kits: Netsilik Eskimo This kit focuses on the seal as the principal source of food, clothing and tools. Films, clothing and tools are provided. The teachers' guide suggests a sequence of activities.
A Children Museum rental Match Box

Skills - Observing - Predicting - inferring

Hopi Indian Kit
Teachers who use this Children Museum Mini Kit use activities concerned with dieties called kadumas. The teacher's guide helps teachers to provide directions for games, to use artifacts and to conduct kadumas dances. It also suggest activities for the principal sources of food---corn, beans, and mellons.

Skills - Observing - Classifying - Recording

Algonquin Indian Kit
Children learn about the Indians inhabiting Massachusetts at the time of the Pilgrims.

Grade 2 Social Studies - annotated listing

Text: Silver Burdett Communities and Their Needs
This text introduces children to Community living; Community change; Environment and and Community; Understanding one Another; Learning and Making Rules in the Community

Kits Houses
This is a Children's Museum Match Box rental Kit. Children actively participate with models of human dwelling from grass and adobe huts to igloos.

Skills: Observing, measuring, using numbers, classifying

Grade 3 Social Studies - annotated listing

1976-77 is a transition year. We have recognized that American History has not been taught extensively anywhere in the Social Studies Curriculum. For this reason the Allyn Bacon Program - the History of Anglo America seemed more appropriate than the current Silver Burdett Program.

People Use the Earth

The Making of Our America

This text describes the historical development of the United States and Canada with emphasis on colonization, the Revolution and the Constitution, Civil War, Westward Expansion, individualization, and urbanization.

Metropolitan Community

The nature and problem of urbanization and urban life style are studied in the light of history, geography, economics, sociology, and politics and an imaginary city.

Kits: The Acton Kit

Developed locally by Acton teachers. This kit emphasises the historical rise of this community. Artifacts and activity provide a rich source of understanding.

Green Circle

Opportunities and tasks which help children experience brotherhood. Children assume different roles as the whole class participates.

Grade 4 Social Studies - annotated listing

Texts: Agriculture-Part of the Allyn Bacon series this manual traces the history and evolution of agriculture. Significant inventions to climatically influenced crop zones are the focuses. Methods of food production and distribution are linked to geography, cultural motivation, economics, social traditions. This book illustrates rice growing areas of Java and Texas and wheatlands of the Great Plains.

Text: Industry: Man and Machines; Allyn Bacon
Mass production and mass consumption are linked social structures influenced by the role of specialization, research, and capital investment. Food processing, automotives, the garment industry and computers all have social, economic, political implications for children. The role of government is also examined in economic affairs.

Kits:
The Great Plains Kit has been developed by local teachers. Teachers have gathered materials for inclusion in each section as follows:

1. grasses and grains - children examine and plant common grasses and grains. Grains are ground for meal.
2. Indian of the Plains--Songs, dances and cultural lore are presented to children through records, paper backs and Indian paraphernalia
3. Cowboys - Cowboys followed Indians onto the Plains. How did they live? Artifacts focus children understanding
4. Farming - This section provides written material, records, and clothing. Objects similar to those used by early western farmers are used by the children to gain some sense of the farmers' life style.

Grade 5 Social Studies - annotated listing

Texts: Ancient Civilization; with this text begins the systematic study of major episodes in world history. Sumer is examined as the earliest civilization.

Four World Views
From the sixth century world views of Confucianism, Buddism, Judaism, and Greek naturalism children explore the way peoples accept their beliefs and how these beliefs influence the way they see the world.

Greek and Roman Civilization
The orgins of our own Western culture has been influenced by the Greeks and Romans. Athen under Pericles and Republican and Imperial Rome are pathways to studies of early christianity and the origins of Western Civilization, Judio-Christian and Greco-Roman traditins.

Text: Medeival Civilization-Iglau, the dominant world civilization of the Middle Age is studied and composed with civilization of Latin Christendom in the HIGH MIDDLE AGES

Kits:
The House in Ancient Greece
A commercial Kit owned by the schools in system. Children participate in an imaginary excavation of an ancient Greek house site and discover in obvious rooms artifacts which tell much about the life style of its early inhabitants.

The Medeival Kit - This is a rental kit from the Children's Museum. The children participate in a play depicting a trail of deer poacher.

Grade 6 Social Studies - annotated listing

The Age of Western Expansion

The rise of Western European culture as a result of the influence of modern techology; the root of Western power in modern history, are facused upon in this manual. Also, emphasized in this text are the formative period of Western civilization highlighting Humanism, religious schism, science, national monarchies, and the decline of medeival constitutional governments.

New World and Eurosian Cultures

This text describes early civilization in America, emergence of Russia, the Moslem Conquest of India, and Japan under Hideyoshi

The Challenge of Changes and The Interaction of Cultures

The political evolution of 18th century Eqrope is explored through considerations of French Revolution and the Napoleonic Wars. The economic and social revolution in industry, science, agriculture, applied science, technology, capital accumulation and population expansion are viewed in terms of their influence on non Western civilizations.

Kits

The Russian Family Kit

Produced by SEE (Selective Educational Equipment) this kit presents the daily life of an apartment dwelling family in Moscow. It helps children to visualize the life, eating habits, working schedule, amusements, recreations, and cultural activities of an urban family. Children can compare the day to day life of the United States urban dweller with the Moscovite.

- SKILLS AND BEHAVIORS

Observing
Level

1. Matches natural objects for likenesses and differences.

   Uses one more of the five senses appropriate to the task to be completed.

2. Relates observation and recording.

3. Demonstrates increased degrees of discrimination with a given object.

4. Uses observations to another prediction.

5. Uses microscopes, telescope, etc. to increase sensitivity and discrimination.

6. Uses a number of observations of the same phenomena to determine the range of responses - uses averages of observations to minimize error.

- SKILLS & BEHAVIORS

Classifying
Level

1. Classifies prepared objects by single criterior.
   Color simple geometric shapes.
   Classifies natural objects by single criterior.
2. Classifies by two criteria.
3. Classifies by reaction of material to operation.
   Classifies by three or more criteria.
   Classifies by behavioral patterns.
4. Classifies by location plus their interaction in space and time - ecological classes.

- SKILLS & BEHAVIORS

Controlling Variables

1. Identifies variables related to an investigation.
2. Identifies and names variables held constant.
3. Identifies variables held constant, manipulated variables, and responding variables
   a. As from reading passages
   b. Within experiments

- SKILLS & BEHAVIORS

Defining Operationally is a statement or statements describing the functional relationship between or among objects, processes, or phenomena.

1. Distinguishes between operational and non-operational definitions.
2. Identifies an object on the basis of an operational definition.
3. Demonstrates the use of an operational definition.
4. Construction operational definition.

- SKILLS & BEHAVIOR

Formulating Hypotheses the process of designing statements which are testable

1. Distinguishes between statements which are hypotheses and those which are not.

   Constructs statements which are hypotheses

   a. from a set of observations

   b. about the relation of alcohol to duphnia photo-tropic movement

2. Constructs more than one hypothesis from given data

3. Identifies data collected from a test constructed by the child that support or do not support hypotheses.

4. Constructs a revision of a hypotheses given results of a test of the initial hypothesis and set of addttional observations.

- SKILLS & BEHAVIORS

Interpreting Data

1. Demonstrates a procedure that uses a fundamental unit of measure.
2. Identifies sets of data in terms of measures of central tendency.

   Constructing estimates or predictions from data charts.
3. Describes how one variable depends on another.

- SKILLS & BEHAVIORS

Measuring

Level	
I	1. Makes comparisons (without instruments) of objects using the senses - length, area, size, weight.
	2. Makes comparison of objects with instruments, metronome, ruler, thermometer.
	3. Demonstrates need for standard units of measure.
	4. Uses standard units of measure.
II	5. Interpolates
	6. Uses metric measure
	7. Extrapolates
III	8. Uses compass
IV	Repeats measurements of the same phenomena to find the change
	Computes averages

- SKILLS & BEHAVIORS

Reading

1. Uses appropriate trade books, to find background in subject areas.

   Uses trade books to serve operation definition.

2. Cites trade books for some procedures
   Use index to find relevant topics

3. Uses trade books for finding alternative models for those proposed in colloquium.

4. Add some Cortland elements.

- SKILLS & BEHAVIORS

Recording

1. Uses cut paper strips for graphing.
   Reads and interprets simple picture graphs.
2. Makes simple map of study site.
3. Constructs line graphs from data of one variable when given a second variable.
4. Records repeated measurements and calculations of averages
   Uses meaningful sentences to record operations and outcome.
   Designs own record form.

- SKILLS AND BEHAVIORS

Affecting

1. Being aware that objects, persons, phenomena exist.
2. Being able to judge the relationship between objects.
3. Values, objects, persons, phenomena--mother, George Washington, Statue of Liberty, Freedom.
4. Evolves a value system.

- SKILLS AND BEHAVIORS

Inferring - the process of identify or explaning project, process or phenomena based upon observations or data available

1. Distinguishes between statements of observations and those that are plausible explanations
2. Identifies statements that are inferrences
3. Identifies statements based upon observations from those which are not.
4. Orders inferences with respect to reliability
5. Constructs inferences
6. Distinguishes between statements that are predictions and those that are inferes.

- SKILLS AND BEHAVIORS

Predicting - the process of describing expected cotcomes

1. interpolates when data are not available ie, fills in the holes.
2. extrapolates when data are not available ie, extends the data logically when given sequence of information--(fills holes not yet made
3. Constructs predictions based on graphs and on data recorded by other children
4. Revises prediction based on additional data.

SKILLS FOR MAJOR SCIENCE UNITS

	forms hypothesis	controls variables	interprets data	states operations definitions	predicting	inferring	recording	affecting	measuring	classifying	observing
Grade 1											
Clay boats	x	x	x		x		x		x	x	x
Fluids	x	x				x	x		x	x	x
Growing seeds		x	x				x		x	x	x
Seed dispersal					x	x	x			x	x
Material objects		x			x	x		x		x	x
Organisms			x		x	x	x	x	x	x	x
Outdoors					x	x	x	x	x	x	x
Grade 2											
Sink & float	x	x	x		x	x	x		x	x	x
Primary balancing			x		x	x	x	x	x	x	x
Interaction & systems		x	x		x		x				x
Magnets					x		x		x	x	x
Simple machines	x	x	x	x	x	x	x	x	x	x	x
Life cycles	x		x	x				x		x	x
Nutrition			x				x	x	x	x	x
Grade 3											
Mystery powders	x	x	x	x	x	x	x		x	x	x
Solutions & crystals	x	x	x	x	x	x	x		x	x	x
Eggs & tadpoles	x		x		x	x	x			x	x
Chemistry	x	x	x	x	x	x	x		x	x	x
Subsystems & variables	x	x	x	x	x	x	x		x	x	x
Populations	x		x		x	x	x	x		x	x
Animals	x		x	x		x	x	x	x	x	x
Friction	x	x	x		x	x	x		x	x	x

(continued)

SKILLS FOR MAJOR SCIENCE UNITS

	forms hypothesis	controls variables	interprets data	states operations definitions	predicting	inferring	recording	affecting	measuring	classifying	observing
Grade 4											
Weather	x	x	x	x	x	x	x		x	x	x
Pond study											
Pendulums	x	x	x		x		x		x		x
Fluids	x	x	x	x	x	x	x	x	x	x	x
Relative motion		x		x			x		x		
Earth & space	x		x		x	x	x	x	x	x	x
Crayfish		x			x		x	x			x
Grade 5											
Mealworms	x	x					x	x		x	x
Ice cubes				x		x					
Gases & airs	x	x		x	x		x		x		x
Energy sources		x	x	x			x		x		x
Batteries & bulbs	x	x				x	x				x
Machines		x									
Light & lenses	x					x			x		x
Grade 6											
Kitchen physics		x			x		x		x	x	
Small things		x					x		x	x	x
Daytime astronomy	x		x		x		x		x		x
Models	x	x	x	x			x		x	x	
Chemistry	x	x		x		x					
Human body	available in late 1976-77										
Electricity	x	x	x			x					

Evaluation -

A. Formative Evaluation

One means by which the statements of children can be evaluated as they evolve and form is developed below. It is one of two systems for formative evaluation. The one below depends on the growth of word meaning from a concrete sense to an abstract sense. The word meanings are inferred from the statements children make following the investigation phases of a lesson.

Another means for identifying the evolution of children's thought lies in the determination of the logic that children use to describe the relationship among objects or phenomena. In this case we shall depend heavily upon Pioget for the development of these logical operations.

SCORING SCHEME

Brenda Lansdown's* scheme is to be used in rating the level of conceptual thinking of the children as expressed in their statements. There are four levels. At the lowest level is SYNCRETIC thinking where a st a.tement shows a perceptual relationship between two or more objects or events linked together but without a logical or functional relationship between the objects.

Esamples: 1. The stone sinks because it is black.
2. It's raining because I am sad.
3. When I sneeze the seltzer fizzes.
4. I will not open this book. It makes thunder come.

The next level is COMPLEX Thinking. Statements falling i into this category are characterized by the grouping of things or events on the basis of external likenesses or common atributes. These attributes may be color, size, shape or functional similarity.

Examples: 1. All red flowers belong together.
2. There are black clouds in the sky, so that's why it's raining.
3. It was so hot that the termometer went up.
4. The onion skin with red dye on it looked like honey-comb.
5. The flower pots were kind of fun. They were kind of like xylophones.

The first two levels are based on the perception of external attributss. The last two levels are based on finding hidden attributes or likenesses which link up objects or events. The third level, PRECONCEPT thinking, is characterized by the grouping of things or events on the basis of hidden likenesses, but in picking out the similarities, one's attention is given to some attributes rather than to others, thus retaining residues of the concrete. The statements seem similar to adult conceptual thinking, but which nevertheless have a concrete base.

* Teaching Elementary Science: through Investigation and Colloquium

Children enter this stage when they begin to use abstract terms instead of the sense perceived.

Examples: 1. A carbonate fizzes in an acid.
2. Plants make sugar by photosynthesis.
3. A falling ball interacts with gravity by falling.
4. Fossils are older the deeper down you have to dig for them.
5. Bigger things have more space to make more noise. Like the flower pot has more air inside so the sound goes through more air.
6. Because there was no air left to let it burn.
7. The bell won't ring 'cause there's no air.

The fourth level, CONCEPT thinking, shows descriptions of situations without rocting item in the original phenomena. Ideas are formulated on a purely abstract plane; without any reference to the concrete or sense impressions. According to both Vygolsky and Piaget, a full flege concept is possible only at adolescence. A concept in this sense combines an abstraction to an abstraction without reference to the concrete.

Examples: 1. Interaction with gravity produces an accelerated motion.
2. Sedimentary strata hold fossils which are related to the era of sedimentation.
3. A carbonate interacts with an acid to give off carbon dioxide.
4. Chloroplasts in plants use the energy from the sun to combine carbon dioxide and water forming carbohydrates and oxygen.

We will further examine each statement to determine whether or not it represents perceiving external or hidden likeness. Objects or events can be compared at either the external or hidden levels. We will score a statement 'COMPARED' if the statement relates one object or event to another through some sense perceived feature of the object or event.

Examples: 1. The onion has larger cells; the scallion smaller ones.
2. Some sounded high, some sounded low.
3. Some of the rubber bands were thick, and some were thin.
4. They went from skinny to fat.
5. The flower pots were like xylophone.

On the other hand we will score a statement as ANALOGY when it groups together two or more things or events with no tangible links through a similarity created by the speaker or which the speaker does not know is a real bridge. These are statements which represent an attempt at elegant thinking, intellectually perceiving a likeness and making a comparison through some kind of an imaginative leap.

Examples: 1. It (a wiffle ball) floats, just like a boat.
2. I think the (flour) paste looks like what my mother makes when she bakes a cake.
3. The flower pots are like people. Big people and big pots make deep sounds.
4. They (onion cells) looked like bricks.
5. It's like the bottle with no air. He stopped the air in the hose.

A MODEL is an elegantly constructed explanation of some natural phenomenon. It goes beyond the facts and provides a new way of looking at observed relationships. It is always a mental image which helps to explain reality. Children who offer explanation of facts and events they have observed are engaging in model making, but at their level. We are interested in this level of explanation and not its rightness or wrongness. We will consider all children's explanations of phenomena which go beyond the facts and have elements of constructs as MODELS and score them as such.

Examples: 1. The electrical energy gets used up as it goes through each light.
2. There is some kind of power going between the ends of my magnet.
3. Because there was no air left to let it burn.
4. The bell won't ring because there's no air.
5. 'Cause everything you say goes right in the hose and out the other side.

Each statement will be scored as expressing complex or preconcept thinking, as perceiving external or hidden likeness, compared or analogy and as a model or nothing. (We expect that the children involved in the experiment will make statements mostly at the complex and preconcept levels in the Vygolsky levels.) Some statements may not be scorable under all three categories. Some may fall under two categories, or one or nothing.

(continued)

	Vygolsky Level	Comparisons	Model
1. It is like the bottle with no air. He stopped the air in the hose. (From an experiment on sound)	Precon.	Anal.	
2. Mine looked like brown bricks (Lesson on cells)	Compx.	Anal. Comp.	
3. Your slide wasn't clear.	Compx.	Comp	
4. Mine was like Ronnie's but darker.	Compx.	Comp	
5. The tree is tall			

B. Summative Evaluation

Various machanisms--paper and pencil tests, the practicum, the field test will be used as instruments for final of summative eveluation.

Organizing the Investigation and Colloquium Lesson *

Investigations and colloquium are not new, you probably have been involved in features of both frequently. If you have encouraged children to manipulate materials then they have discovered new relationships through investigation. If you have conducted discussions with children in the course of these investigations or after then you were probably following many of the percepts of the colloquium. These discussions (colloquium)are critical for learning.

The aim of science learning is to foster conceptual growth. Therefore, the use of language in relation to the development of concepts is crucial. Many teachers have been rightly critical of some of the science units, for example, whose authors seemed to encourage manipulation of materials without encouraging verbal interactions which would help children conceptualize their actions on materials and objects of the lesson.

Each lesson in this project has linked the manipulation of materials with discussion. Below we present an initial lesson on the pendulum -- "The First Exploration of the Pendulum" which help children relate investigations to colloquium

Investigation --

The materials selected and the tasks suggested are carefully chosen for each lesson. The materials should possess inherent relationships. When children manipulate them, different but definable results are obserable. In this activity children can manipulate:

1. the length of the pendulum
2. the weights or masses on the pendulum
3. the push given the pendulum
4. the angle of initial release of the pendulum bob

The task is: Do pendulums move back and forth at different rates? If so, what influences them?

These inherent relationships, length of pendulum, weights, angle of release, and push are structured by the equipment available to the children. The task establishes the goal of the lesson.

*Example from a Fourth Grade Unit

Swings, Seesaws, and the Pendulum:

An Extension of the ESS Pendulums Unit

Lesson # 1: The First Explorations

Skills

Observing

Uses observing to make predictions

Measuring

Designs devices to measure motion of the pendulum

Controlling Variables

1. Defines variables applicable to the problem
2. Manipulates variables to make accurate predictions

Content: Investigation Phase

Background information:

This first experience with materials is highly structured by the pendulum equipment. Children attempt to find out if pendula move back and forth at different rates. When linked with skills which are non graded the lessons on the pendulum take on a more universal quality.

Materials

Pendulum rack or cross bars, paper clip, hooks, fishing string, # 5 1-hole rubber stoppers, sweep 2nd hand clock (optional)

Procedure:

1. Pass out equipment and help children set up equipment. See resource teacher if you have any questions and if the instructions for setting up the equipment are not in the manual or kit are not clear.

2. The number of children working together may vary from two, three, or four. One effective grouping has two pairs who work in a cluster with two sets of apparatus shared among them.

3. Suggest the task: Do pendulums move back and forth making the same number of round trips in thirty seconds? How do they account for the differences?

The Colloquium

The discussion following the experience with material sharpens perception from observations shared in the group. The teacher's role in the colloquium is to help children express thoughts clearly, to supply the right word at the right time, and most important of all to provide the psychological safety to protect the efforts of each child.

Children raise new questions which stimulate future investigations and through the support of the teacher children resolve discrepancies in observations. In the first colloquium not all children wish to participate. In later discussions when some children feel more secure they provide answers that are very insightful. The colloquium is usually initiated by asking the students to describe one observation or one action. We encourage children to limit their discussion to one contribution to encourage participation by a maximum number.

The Colloquium is based on three major questions:

- What observations did you make?
- How do we solve the problem of differing results from the similar experiments?
- How do we explain the major results of the experiment?

INITIATING THE COLLOQUIUM

INSTRUCTOR: Please give us your name and then tell us about one observation that you made or one thing that you did during the session. This will give everyone an opportunity to suggest one thing that they had done.

Kristen: The string that is longer when compared to the shorter pendulum will go more slowly than the shorter string.

Laura: When the cross-piece to which the string of the pendulum is attached is loose, the pendulum will go more slowly.

Linda: If the string is shorter than the other, it will go farther.

Karen: The pendulum, that is, the bobs will tend to go longer even though the string is shorter.

Karen: If one person is holding both of the stoppers, bobs, it is much easier to get them going.

Julie: If there are five stoppers held right next to each other, they will move back and forth.

INSTRUCTOR: They go in and out?

Julie: They go in kind of a V path.

Victor: When you let the bobs go, they begin to go in a slant, but if you let them continue, their path changes and ultimately they will go straight back and forth.

Paul: If the legs of the pendulum stand which resembles a saw-horse are different distances apart on each side, the cross-bar is angled being lower on one side than the other, then the strings appear to be different lengths and the pendula tend to swing differently.

Cortell: Most of the time when I was swinging the pendulum they went from more than a minute and a half.

INSTRUCTOR: And they would stay together?

Cortell: Yes.

Mark: If you could get them to swing together you could make different patterns out of the way they swung by letting them go different ways.

INSTRUCTOR: Patterns of movement?

Mark: Yes.

(continued)

(continued) Initiating the Colloquium

Andy : When the cross-bar is slanted the pendulum tends to move in a V or inverted V.

Beth : Our bobs wouldn't work right. After 5 seconds they wouldn't be going together.

Cheryl: It is hard to get the pendulums to go together. Most of the time it doesn't go very long. If you make the string shorter, then they tend to go together a lot longer.

Patty : Most of the time with our pendulum they would swing for about five seconds and then they would go uneven.

— The instructor tends to support the discussion by intervening in the discussion rather thru intruding. An intervening question or statement tends to clarify, encourages children to construct models (explanations), stimulates new investigation, and enriches the coalescing of thinking and language into thought. At this point the teacher juxtaposes conflicting observations and encourages children to resolve these conflicts. Such a conflict is posed by instructor below:

INSTRUCTOR: Some of us were able to have our pendulums swing together for longer periods of time than others. Did anyone discover why that might happen?

Kathy: If the strings were different in length, they probably wouldn't go together. The one that is shorter tends to go faster.

Cheryl: The one with the longer string tends to go out farther and the one with the shorter string tends to go up higher.

Laura : The pendula functioned differently if you gave one a push and just released the other. If you start them at different times they will form different patterns of movement.

— The average colloquium lasts twenty minutes in the intermediate grades. This one was limited to ten minutes because of the nature of the study of which it was a part. The final phase of the colloquium asks children to summarize the observations and understandings of the lesson.

INSTRUCTOR: Are there any other factors that can influence the way pendula swing together? If the pendulum cross-bar is slanted this seems to give different results when the pendulum is swung. Are there any statements that you think we could all agree upon?

Andy: The length of string determines how fast it does.

Mark: The legs on the pendulum stand have got to be the same distance apart.

CLAY BOATS EXTENDED

Marilynn Due
Summer, 1976

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CLAY BOATS EXTENDED

Materials

modeling clay
plastine
trays or buckets
multi purpose balance
pails
wax paper
eye droppers
dowel rods
globe
Silver Burdett Pictures

Skills

observing
classifying
recording
interpretation of data
predicting
control variables

Operations

graph
buoyancy of objects
comparison of weights
floatation - high - low in water
investigate salt in water

Expeximentation

buoyancy
surface tension
adhesion
floatation
sinking
properities of water
experiences with substances & volume

INTRODUCTION

You may not be thinking of water as one of the most interst-ing, as well as, one the most necessary substances in the world.

People can live without food for as long as thirty days but not as long without water. Bodies of animals are more than seventy percent water.

Water is used inside the plant and animal for many purposes and great quantities are being passed off into the air all the time.

This wonder substance which coveres three-fourths of earth's surface occurs as a gas, as a solid (ice), and as a liquid. Water absorbs and gives off heat slowly which affects the clima-tology of land masses of the earth.

Many substances dissolve in water but may not react with it chemically. Water transports salts and gasses without change.

All life is dependent upon water in some manner. As the world's population soars and modern technology creates changes in living conditions greater demands on water resources will be inevitable.

There is water deep in earth, air is ladden with water, and water is piled up in polar regions (in frozen forms).

Even young children can begin to appreciate the significance of water useage in their lives and begin to relate to the physical qualities of this "wonder" substance.

When encouraging young children to use their experiences and knowledge to attack new phenomena the pedagogy must move in the immediate realm of the child's command and natural surroundings moving, using real experiences with actual phenomena, forces and things.

Firsthand experiences are in the last analysis the basis of learning. We do not intend to develop little "scientist" but do intend to encourage building of preconceptual objectives which enables children to cope more effectively with materials, forces, and events.

Piaget and Vygotsky, developmental psychologist, concur that pre-school and early elementary school children generally work on a preconceptual level. Concepts are usually formed slowly and require a wealth of relevant experiences. Seldom can one child develop a concept from a single lesson on a science topic. Teachers should provide organized, meaningful, experiences which will enable the hierarchiel development needed by children. Teachers should guide purposeful questions and meaningful vocabulary during colloquium ciscussion.

We have tried to extend the ESS unit Clay Boats by providing the children with logical hierarchiel path from the creative play activities in kindergarten to more understanding of water; and therefore, hopefully, better abilities to understand some primary phenomena presented in clay boats.

Teachers should schedule and handle the units to suit their class time frame, etc.

Following each procedure area will be suggested question cards or activity cards for teacher used primarly to help stimulate the class activities. The cards can be run off on oak tag, tied together, used as flip through on the spot assistance. Some cards give possible responses students might make to help teacher recognize unusual thoughts from students concerning the experimentation.

Materials Used For Clay Boat Unit

Materials

globe
containers (various sizes)
markers
pictures (Eskimo, Indian)
Silver Burdette pictures
magazine pictures (Indian, Eskimos)

heating unit
tea kettle
ice cubes
shallow bowl

cactus plant
oranges
tomato
green leaf and/or flower petal
grapes
container for sand, water, split peas

candle
bucket
cork
stopper & bottle
balloon
jars
clay
string
foil
paper
wood
clay
1-cm cubes
paper clips
other lightweight material, cloth strip, paper strip, tape,
paper cups, straws, 2-milk cartons, ruler
aluminum
paper towel

cups
pencils
2 containers
large water container
small amount of clay
dowel rods
wood pieces

RESOURCE LIST

Suggested resource materials which may be used among other materials that are available.

I. Films

A. Boston University
Instructional Films
Krasker Memorial Film Library
B. U. School of Education
765 Commonwealth Avenue
Boston, Mass. 02215 Phone 353-3272

1. Water a First Film
16 min color rental $7.50

Presents a series of experiements which show that when an object is submerged in water an apparent loss of weight results.

2. Water - a First Film $5.00 rental
11 minuites

Explains water as important part of our world. Shows that plants and animals cannot live without water, uses of water and avoidance of misuse.

B. Douglas School

Film Strip	551.6 W	Weather - Why does it rain?

C. Merriam

Film Strip	551.4	Oceans
Film Strip	551.6	Adventures of a Raindrop

D. Conant

Film Strip	532	Water and Its Uses
" "	551.6	A Rainy Day
" "	551.6	Why does it Rain?

E. McCarthy-Towne

Film Strip	551.5	How does water get into the Air?
" "	551.5	Where do Clouds Come From?
" "	551.5	What Makes Things Dry Faster?

F. Gates

Film Strip	551.6	Finding Out About Clouds
" "	581	Green Plants Need Water

II. Books

The Boston Museum of Science Library

1. Water is Wet - Sally Cartwright; Coward, McCann, Geoghegon Inc., N. Y.
2. Water All Around - Tillie S. Pine, Joseph Levine; Whittlesey House, McGraw Hill Co.
3. 700 Science Experiments - Compilied by UNESCO, 1962 Doubleday & Co., Inc., N. Y.
4. Floating & Sinking - Franklynn Branley; Cowell co., N. Y.
5. Science - McGraw-Hill Co., P. 98

(continued)

(continued) Resource List - Books

6. Teaching with Everyday Things - Schmidt, Rochcastle McGraw-Hill

7. Teaching Elementary Science Through Investigative Colloquium; Landsdown

8. Information Early Experience Series - MacDonald Educational Beginnings

Other materials through Libraries

Douglas TRA 50303 Solid Liquid Gas

Silver Burdette - "The Earth, Home of People" series used in first grade

GLOSSARY

adhesion - attraction between unlike molecules (water molecules adhere better to glass than to water molecules)

buoyancy - water's magic which we may take for granted is its ability to transport objects

cohere - cling to itself - molecules of water clung to more like molecules

motion - changes of instant or immediate nature

surface tension - water and other liquids have a thin film which covers their surface. The surface film is pulled tightly over the liquid

conservation of volume- described as experiences with substance and volume in this unit

LESSON I

The significance of water in the life cycle

PART I

Are the children aware of the total effect water has on the processes of living animals and plants?

Skills & Behaviors

* 1. Observing & Recording
relates observation & recordings to amount of rain water caught
relates observation & recording to evaporation of water from containers

2. Classifying
classifies amount of water on earth according to size of body of the water (sea, stream, lake, puddles)

Materials

globe
containers for catching rain water
containers for showing evaporation
markers
maps
Silver Burdette - "The Earth, Home of People" Social Studies text and picture set:
Picture # 16 (shows water & landmmass)
" " 18 (same)
" " 20 most of earth is covered with water

Content

Three-fourths of earths surface is covered with water. Without water there could be no life on earth. The need for fresh water has become so urgent that sixty-two (62) nations are cooperating on desalinizations research.

Procedure

The class division is the teacher's choice based on knowledge of class, etc.

Catch rain in containers and mark the container showing rain over several day period.

Let the containers stand and watch the evaporation process for several days marking the water level after each observed decline in water level.

(continued)

(continued) Lesson I

See note cards for questions to guide the activities.

Use a globe, pictures and/or Silver Burdett picture series. Use the following question or activity cards to stimulate discussion about the evaporation process and the size of bodies of water on earth.

Where did we get the rain water?	How much water is missing (on second day)? Third, etc. What happened to missing water?

Using map or globe Where are largest amounts of water? Smaller? Where have you seen water?	Draw a picture including some of these---a river, an ocean, puddle, lake or stream

Colloquium

Why was more water caught today than yesterday?

When it rains can we tell by watching whether a lot of water will be caught? Small amount?

Tell about size and movement of bodies of water, river, stream, ocean, lake, etc.

What affect does amount rain water bodies of water have on animals of the area?

LESSON II

The significance of water in the life cycle

PART II

Children should be aware of importance of water in our daily lives and in the daily lives of the Eskimos and Indians. Two cultures we discuss in Social Studies units at first grade level.

Skills & Behaviors

Observing

Use observations from the past to relate information about Indians and Eskimos

Uses senses to discern particular uses of water for self

Classifying

Classify by culture how water is used

Recording

Make simple graph for personal water use

Materials

Eskimo & Indian pictures from the units if possible

Silver Burdett -- 1st. grade Social Studies Text has a section on Indians Pictures from magazine cut out by children on water usage.

Content

Background

This short simple lesson is designed to help children broaden their understanding of uses of water beyond selves. We hope to help children understand that all kind of people use water in a similiar manner.

Procedure

If the Eskimo & Indian units have been studied a discussion could begin with the picture.

How they used water. Assign children to bring in pictures of uses of water. Give each child a ditto graph chart indicating some of the personal water uses.

--Name--_____					
drink	wash	play	cook		other

(continued)

(continued) Lesson I.

Children can color in a rectangle everytime they make a use of this area. Examine and discuss in terms of WHO colored in more rectangle in "drink" column, play area, etc. Why?

Use pictures

Where did Eskimos get water?	Where did Indians get water?
How did they use water?	How did they use it?

Where do you get water?

How do you use it?

Evaluation

Draw pictures of themselves, Indians or Eskimos using water in some manner. Their colloquium discussion would really take place during general discussion sessions in this lesson.

LESSON III

PROPERITIES of WATER

This lesson is added to the unit to help children make judgments concerning the physical states of water -- liquid, solid, (ice) or gas (vapor)

Skills & Behaviors

Observing

Uses five senses to detect changes in the states of water

Observes the physical changes needed to get water from liquid to ice or liquid to gas

Controlling Variables

Identifies variables related to investigation (water, ice, boiling water)

Measuring

Make comparison of amount of water used at the beginning of the experiment

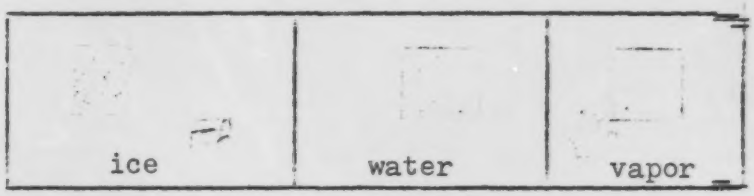
Make comparison between ice cubes and amount of water melted.

Materials

heating unit
container of water
tea kettle
ice cubes
glass
shallow bowl

The day before put water in ice cube trays to freeze.

Pour water into another container. Let children observe in terms of how the liquid leaves container. Put ice cubes in a shallow dish. Begin heating the water in kettle on stove. Make a chart showing molecules placement in each of three states



Question cards to stimulate a colloquium.

What do you notice about the liquid? (as you pour)

Would ice pour the same way?

What happens when water is put in a freezer? Note change in ice cubes when set aside in bowl at room temperature.

What happens when water is heated?

*Optional

(continued)

(continued) Lesson III

Evaluation

What happened to the water when it was heated?
What happened to the water when it was frozen?
When are parts (molecules of water (as a liquid) farther apart? Closer together?

LESSON IV

HIDDEN WATER

Children generally become acquainted with water around them by visual contact or use contact. They need to be aware of hidden water in plants, air and fruit.

Skills & Behavior

Observing
Identifies experiments according to whether or not "hidden" water is found

Predicting
Able to infer where water will be found in plants, fruits and under ground

Materials

cactus plants
oranges (other citrus fruit)
tomato
green leaf and/or flower petal
grapes

Water is all around, listen to raindrops, watch streams, watch waves, drink water. Are there places where we can't see water? In plants, foods, and underground can find water.

Have samples grapes, oranges, tomato slices, green plant leaves, flower petals. A cactus plant maybe displayed. Follow suggested questions on activity cards. Select children to have turns sampling the fruit or give each child one or two samples.

Bite into tomato, eat a grape, squeeze an orange. What happens?

Rub green leaf and flower petals between palms of your hands. What happens?

Cut a cactus plant. What happened?

Can you think of other foods that contain water?

Evaluation

What happened when we bit into the fruit?
What happened when we cut the cactus?
Why did the liquid sometimes "pop" out?

LESSON V

EXPERIENCES

Investigation of volume using different materials poured into containers different sizes and shapes to determine consistency.

Skills & Behaviors

Controlling variables

Identifies quantity of variables (water, sand, split peas) related to this investigation.

Interpreting Data

Demonstrates procedure that specifies unit of measurement used to fill the various containers.

Measuring

Makes comparison of the materials used to fill the containers.

Materials

large container of sand, water, split peas
3-4 smaller containers of various sizes, shapes
2 tubes, long and short
small measuring unit (½ cup size) (let children select this unit from classroom materials)

Content

This lesson can be used to help children begin to visualize and preconceptualize that change in shape of container only appears to make a difference in quantity of materials.

Set up three areas for investigation. One for each material to be used. (sand, peas, water)

Children can be grouped according to teachers insights and children's needs. Smaller groups seem to work best (½ of class).

Take a group to each area let them follow the same general procedure at each area. One adult at each station works well then rotate stations.

One small group can be taken through the three stations then another, etc.

Fill each of the containers with same amount of material (sand, water, split peas). Do all stations using same unit of measure.

Turn tubes on sides and upside down to investigate.

(continued)

(continued) Experiences Lesson V

Which container has most? (water, split peas, sand) (depending upon your station) Responses may be: The container showing the highest level of material has the most. If you ask Why? How many units of peas did we put in each?	Which container has least amount?

Is amount the same when containers (especially the tube is tilted?

Children tend to respond that there will be more material in tube when it is upright.

"Did any leave the tube?"

Evaluation:

When you looked at different containers did any one look as though more was in it?

Why did it look like this?

How do you know the amounts were not different?

LESSON VI

BUOYANCY

To carry trhough with volume concept in Lesson V we will use clay among other materials to investigate the possibilities of changing a small lump of material into something with buoyancy. This lesson may take two or three sessions of 15 - 30 minutes.

Skills & Behaviors

Controlling variables

Identifies the amount of materials related to the investigation of buoyancy

Observing

Uses senses to form appropriate clay shape that will float.

Materials

bucket
string
clay - enough for walnut size for each child
bottle & stopper
balloon
large container of water
straws

Content

The shape of the object in relationship to the water pushed away enables the objects to float. If the weight of object is same as the water it pushes aside then the object floats.

If weight is added to point that the water pushed aside is not same, then object will sink.

Teacher can use activity cards to stimulate children into involvement in project. Each small group may be doing different buoyancy experimentation.

Put a small piece of clay in your hand. Roll it around. How does it feel? Put it in the water. Does it float? Will a very large piece of clay float? Will a very small piece float?

Which weighs more? Boats that sink or those that float.

(continued)

(continued) Lesson VI Buoyancy

Can you make a shape that will float? Change the shape. Does it float better?

What happens when clay is dropped into water, tossed i into water, placed, etc.

Put something inside your ball. Does it float now? Put some other things inside the ball. Did you make a ball that floats? Will it float for a week?

*Use: foam, balls, wood, marbles, etc.

---

*This can be done in small groups. Put a small piece of clay in your pan. Does the clay float? Try a very small piece. Can you make some clay float?

This floating clay is different. Some other things can be used to float clay. Can you float clay with soda straws?

Metal milk cap flat then rolled into sphere. Which shape floated?

Two soda bottles balanced tied with string balanced on forearm. Bring pail of water up under one of the bottles until it sinks in the water a little way. Observe what happens!

Push a large cork to the bottom of the water. Repeat with bottle & stopper. Is there a difference in force needed to push to the bottom? Repeat with a balloon and push it to the bottom of the pail.

(continued)

(continued) Lesson VI Buoyancy

Tie a string around a rock attach a rubber band to the string. Lift by the rubber band. Notice the stretch. Now lower into the can or pail of water and observe the stretch.

Put nail in lower end of candle- nail weight should be just right to make candle float with its top above the surface of the water. Float candle & nail in tall glass of water, light dandle - watch it burn.

Why does it continue to float?

Evaluation

Their comments during the activities.

What kind of clay floated best?
What else floated? Why?
How did the bottle differ in weight?
What happened to candle as it burned?

LESSON VII

"PASSENGERS"

Using knowledge gained in previous lessons have children experiment with "passengers" in their boats.

Skills & Behaviors

Observing
Relates observation and recording on graphs
Uses more than one of five senses appropriate to the task of applying passengers to the boats

Controlling variable
Identifies variables related to to the investigation

Measuring
Makes comparisons using quantity

Materials

large water container
paper clips - "passengers" or other light weigh classroom material

Content

Using suggested question cards guide children through the activities of making a boat that floats then seeing how many passengers the boats will hold. Make a graph for each child to mark number of passangers added.

Make a boat that floats. Find a way to sink it without pushing it down.

Can you make a boat that floats and holds cargo?

What can you put into your boat? Will it float? Which shape holds more?

Pretend paper clips are people. How many will your boat hold?

Who's boat will hold the most cargo?

Ways to make clay boat hold more:

make sides taller
make it wide inside
make clay thin
dry inside of boat

(continued)

(continued) Lesson VII "Passengers"

GRAPH

NAME	SUE	Bob	Bill	Ann	
8					
7					
6					
5					
4					
3					
2					
1					

Color in number of "passengers" held by the clay boats.

Evaluation

Colloquium

Who made a boat float?
How many passengers could your boat carry?
Why could some carry more passengers than others?
If everyone had boats of same shape would each carry same number of "passengers"?

LESSON VIII

Use many types of materials to discover float and sink abilities.

Skills & Behaviors

Observing
matches objects for likeness and differences in relationship to floatation

Classifying
classifies objects by their ability or inability to float in fresh or salt water

Materials

	salt water	fresh water
aluminum	2 containers	dowel rods
paper towel	large water container	wood pieces
cups	2 hard boiled eggs	any material the
pencils	small amount of clay	children may want to try

Choose various materials and try to float these. Add little clay to the end of a dowel rod. What happens?

Hard boil t. wo eggs. Put one egg in each of two jars, One jar with salt water, one fresh water Which egg rises? Add salt until egg floats

---

Try other objects in salt water and/or fresh

Evaluation - Colloquium

What objects floated? Why did these float?
Which egg floated? Why?

LESSON IX

LADDERS of LIQUID

Water will seek its own level.

Skills & Behaviors

Observing

observes water absorption of cloth, paper towels

Interpreting Data

from experiment which indicate water seek its own level

Materials

strips of paper towel
strips of cloth
paper cups
tape
large milk carton
bucket
milk cartons
straw
ruler

Depending on abilities both to cohere and to adhere liquid ladders often do interesting things such as climb up or down porous materials. Besides being useful in lamp and candle wicks, and in sponges this climbing action provides an intriguing matter to investigate

Follow activity cards

Cut 5" strips of 3 cloth and 2 paper towel. Tape one end of each to a ruler supported by two books.

Attach paper cups to other end and fill with water.

On which strip does water rise faster? On which has it risen faster in 5 minutes?

Cut several equal sized strips of cloth.
Attach one end into pail of water. Attach other end in a cup.

Through which strip does water soak to the point of dripping? Does water stop moving in a strip when it reached soaking point?

Attach two milk cartons with a straw.

1st 2nd

Pour water into first, measure water in both. Are you surprised to see water in the second container is as high as the first? Why?

Cut three holes in a large container. Watch it continue to leak.

(continued)

(continued) Lesson IX Ladders of Liquid

On which strip did water rise faster?
What happened to water in first milk carton?
Which hole continued to pour water until container was almost empty?

LESSON X

MAKING DIFFERENT KINDS of BOATS

Children can make boats from various materials in addition to using clay.

Skills & Behaviors

Observation
relates to material to form a shape which will float

Classification
classify according to number of passengers the boat can carry

Materials

This will depend upon type of boats constructed.

foil	paper cups
paper	paper clips
wood	1 cm cubes
clay	other passengers
construction paper	

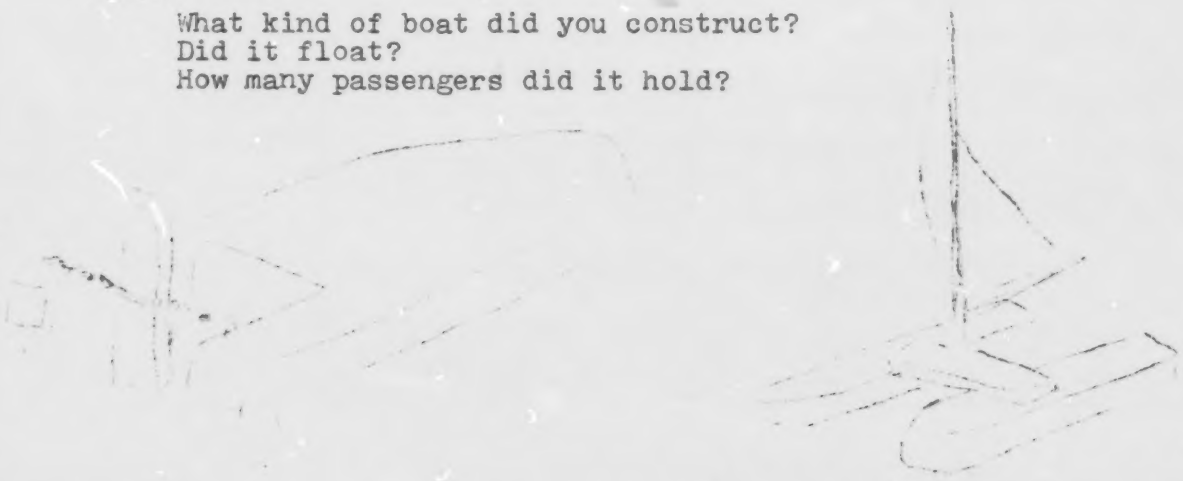
Some children may want to work with simply made boats, others may want to construct more elabrate boats. Adding "passengers" may be of added interest when sailing hese boats.

See drawings for examples of wood boats

Add passengers to boats.

Evaluation

What kind of boat did you construct?
Did it float?
How many passengers did it hold?



LESSON I

Where did we get the rain water?

LESSON I

How much water is missing (on second day)?

Third, etc. What happened to missing water?

LESSON I

Draw a picture including some of these;

a river, an ocean, puddle, lake or stream.

LESSON I

--using map or globe--

Where are largest amounts of water? Smaller?

Where have you seen water?

LESSON II

Where did Eskimos get water? How did they use water?

LESSON II

Where did Indians get water? How did they use it?

LESSON II

Where do you get water? How do you use it?

LESSON III

What do you notice about the liquid? (as you pour) Would ice pour the same way?

LESSON III

What happens when water is put in a freezer? Note changes in ice cubes when set aside in bowl at room temperature.

LESSON III

What happens when water is heated?

* Optional

LESSON IV

Bite into a tomato, eat a grape, squeeze an orange. What happens?

LESSON IV

Rub green leaf and flower petals between palms of your hands. What happens?

LESSON IV

Cut a cactus plant. What happened?

LESSON IV

Can you think of other foods that contain water?

LESSON V

Which container has most (water, split peas, sand)? (depending upon your station)

Responses may be: The container showing the highest level of material has the most.
If you ask Why? How many units of peas did we put in each?

LESSON V

Which container has least amount?

LESSON V

Is amount the same when containers (especially the tube is tilted)?

Children tend to respond that there will be more material in tube when it is upright. "Did any leave the tube?"

LESSON VI

Put a small piece of clay in your hand. Roll it around. How does it feel? Put it in the water. Does it float? Will a very large piece of clay float? Will a very small piece float?

LESSON VI

Can you make a shape that will float? Change the shape. Does it float better?

LESSON VI

What happens when clay shape is dropped into water? Tossed into water? Placed, etc.

LESSON VI

Which weighs more? Boats that sink or those that float?

LESSON VI

Put something inside your ball. Does it float now? Put some other things inside the ball. Did you make a ball that floats? Will it float for a week?

* Use: foam, balls, wood, marbles, etc.

LESSON VI

Put a small piece of clay in your pan. Does the clay float? Will a larger piece of clay float? Try a very small piece. Can you make some clay float?
This floating clay is different. Some other things can be used to float clay. Can you float clay with soda straws?

* This can be done in small groups

LESSON VI

Metal milk cap flat then rolled into sphere. Which shape floated?

LESSON VI

Two soda bottles balanced, tied with string balanced on forearm. Bring pail of water up under one of the bottles until it sinks in the water a little way. Observe what happens!

LESSON VI

Push a large cork to the bottom of the water. Repeat with bottle & stopper. Is there a difference in force needed to push to the bottom? Repeat with a balloon and push it to the bottom of the pail.

LESSON VI

Tie a string around a rock, attach a rubber band to the string. Lift by the rubber band. Notice the stretch. Now lower into the can or pail of water and observe the stretch.

LESSON VI

Put nail in lower end of candle---nail weight should be just right to make candle float with its top above the surface of the water. Float candle and nail in tall glass of water. Light candle---watch it burn. Why does it continue to float?

LESSON VII

Make a boat that floats. Find a way to sink it without pushing it down.

LESSON VII

Can you make a boat that floats and holds cargo?

LESSON VII

What can you put into your boat? Will it float? Which shape holds more?

LESSON VII

Pretend paper clips are people. How many will your boat hold?

Who's boat will hold the most cargo?

LESSON VIII

Hard boil t wo. eggs. Put egg in each of two jars. Which egg rises?
One jar contains salt water, the other fresh water. Add salt until egg floats

LESSON VIII

Try other objects in salt water and/or fresh.

LESSON IX

On which strip does water rise faster?

On which has it risen faster in five minutes?

LESSON IX

Are you surprised to see water in the second container is as high as the first? Why?

A STUDY OF FRICTION

Mark Kaufman

Summer 1976

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INTRODUCTION

The methodology used in these experiments is based on the children working in groups of about four and all children having an opportunity to take part in the experiments. In a few cases, the experiments are best done as demonstrations, but these can also be done by children. If materials and time permit, have the entire class work simultaneously and then take part in the colloquiumphase. In case of limited materials, groups can work one after another and the colloquiumcan take place after the last group has finished. Each experiment can be done in 20-30 minutes. A discussion should last about 15-20 minutes. After each experiment, there are suggestions for extensions and additional experiments. These, too, can be followed by a discussion. Whenever possible, pose the activity as a problem to be solved rather than a formula to follow. This entails asking how can the materials be used to solve the specific problem. In cases where children have trouble finding an approach, the directions can be given. Some description, oral or written, of what each experiment is about will be essential prior to starting a session. The materials are listed in the beginning of each lesson and it is assumed that each group will receive a set of materials. Many of the things can easily be obtained without going to "educational" suppliers. If possible, a kit will be created for non-consumable items.

The ideas and information are a compilation of various sources. Almost every experiment has been tested and can be done with a minimum of preparation. The unit itself is challenging and exciting for third graders. They will need to stretch their minds to find adequate explanations for what seem to be obvious phenomena. With eleven experiments plus extensions, the unit will take at least four weeks, probably longer. I hope that it proves a useful and effective guide.

MATERIALS LIST

(8)	2' x 4' masonite boards - four can be cut from a 4' x 8' sheet of masonite
(8)	hand magnifying glasses
(1 bag)	cotton balls
(8)	mirrors or panes of glass
	dictionaries
	masking tape
	string
(8)	spring scales calibrated in grams or ounces
(50)	round pencils or thin 6" dowels
	large supply of marbles
(8)	coffee can lids with rims
(8)	mayonnaise jars with covers
	soap
(8)	erasers
(1can)	3-in-1 oil
(4)	sheets cardboard 2' x 2'
(4)	sheets cardboard 3' x 4'
(1 box)	kitchen matches - not safety matches
(3)	aluminum pie plates
(1)	hair dryer
(1 pkg)	balloons
	felt or cloth woolen cloth rubber bands
	thumb tacks
	old bike or car inner tube
(16 pcs)	fine sandpaper - 3" x 5"
(48 pcs)	medium sandpaper - 3" x 5"
(8)	blocks rough wood - 4" x 6"
(40)	blocks wood 4" x6"

RESOURCES

Books

Structures and Forces 3, MacDonald Educational
London and N. Y., 1974

Friction All Around, Tillie S. Pine and Joseph Levine
McGraw-Hill, 1960

Slips and Slides, ESS, McGraw-Hill, 1969

A Sourcebook for Elementary Science, Hone, Joseph and Victor
Harcourt, Brace and World, N. Y., 1962

Filmstrip

Overcoming Friction

Experiment 1 - What is Friction?

Materials

2'x4' masonite board
block of rough wood (approx. 1"x4"x6")
piece medium sandpaper - 3"x5"
hand magnifying glass

Skills

observing the differences between several surfaces
Comparing the resistance of the different surfaces
inferring the relationship between type of surface and amount of friction

Background

The resistance caused when two surfaces rub against each other is called friction. The more easily they slide, the less friction is present. If you examine the surface of a block of wood, you will see bumps and hollows and uneven places which make it difficult for the wood to slide smoothly. Even if the block is sandpapered, there are still uneven places, although there is significantly less resistance. In the following experiments, children will examine the basic elements of friction.

Procedure

Either or both of the following experiments may be done to introduce the basic notion of friction.

(a) Using the rough side of the masonite board, have the children slide the wooden block across it, noting the amount of effort needed and the resistance they feel. At this point, their impressions are not really measurable and can't be consistently reproduced. You may want to pose the problem of how to move the block so that you use the same amount of push or pull each time. It would be helpful if somebody devised a way, but not essential. (Try using rubber bands or springs.)

(b) Use the magnifying glass to examine the surface of the block. See if the surface looks smooth, uneven or rough.

(c) Using the sandpaper, sand the surface as smooth as possible. Then try the first experiment again to see if there is any change in the effort needed or in the resistance. If they need to compare, have extra rough blocks available.

(continued)

(d) Examine the surface again under the magnifying glass. See if it looks the same as before or if it has changed.

(e) Questions for colloquium

- What did the surface of each block look like?
- Which block moved more easily across the board?
- If there was a difference why did it occur?
- What changes took place from the first experiment to the second?
- Was the friction greater in the first or second?

(a) In their groups ask the child to list (predict) their shoes in order of the slipperiness of the soles. This can be done by trying to slide across a small area of the classroom floor. Have them keep their list until the discussion. (Note: record the shoes by the kind of sole it has, i.e. smooth rubber, rubber with ridges etc.)

(b) Ask them to remove their shoes and try to slide in their socks. They might also try it in their bare feet--(some may get a floor burn, friction produces heat!!)

(c) If a rug is available try the first two activities on the rug. Note the differences.

(d) Colloquium

- Compile the data from the first experiment. What kinds of shoes slip most? Least?
- Why do some shoes slip more than others?
- Are socks more or less slippery than shoes? Why?
- Are feet more or less than socks? Shoes?
- Was there anything different about sliding on the rug?
- Did all shoes slide the same?
- Were socks as slippery as on the floor? Why?

Experiment 2 - Friction Wears Things Away

Materials

- fine sandpaper - 3" x 5"
- medium sandpaper - 3" x 5"
- rough stone
- smooth and rough wood - available from Experiment 1
- glass surface or mirror - use window if necessary
- cotton balls
- prediction sheet

Skills

observing the textural qualities of surfaces
measuring the roughness and smoothness of various surfaces
predicting which surfaces have the greatest amount of friction
recording information in a chart form
classifying surfaces based on obervation and experiments

Background

Friction wears things out. If there were no ways to reduce friction, tools and machinery would wear out and break quickly. Reducing friction can be economical and safe. In this experiment, children will rub a cotton ball across different surfaces to see which ones are roughest, thus wearing away bits of the cotton.

Procedure

(a) Give each group the two kinds of sandpaper, the rough stone, the two kinds of wood and a smooth glass surface. Ask them to look at the surface and predict which one will trap the most cotton as a cotton ball is rubbed against it (use prediction sheet like sample)

(b) Give each group a few cotton balls and ask them to rub them equally over each surface. Have them record the amount of cotton left on each surface and rank the surfaces in order.

(c) Bring the groups together and make a large prediction chart including each group's predictions. Then beside each prediction, record the actual order of "grabbiness".

(d) Colloquium

- How close were the predictions? Why were they close or not?
- Which surface(s) had the most cotton? Which had the least?
- Why was there a difference?
- What would happen to the cotton if it were rubbed over and over on the rough surface?
- Do things wear away if they are rubbed?
- What did you do in the first experiment that wore something away?

(e) Extensions

- Rub a new crayon lightly across a paper; rub another much harder. Which one wears away more?

- Put a smear or smudge on a piece of wood. Sand it till the spot disappears. What happened?

- What happens to an eraser if you rub long enough?

- Look at the soles of your shoes. What do you notice? Why is this? Do new shoes look like old shoes?

- Look at the tires of different cars. Do they all have the same amount of tread?

- What parts of your pants wear out the fastest? Why is that?

- How many things can you find that are worn down because of friction?

- Sharpen a knife on a grindstone or whetstone. The knife becomes sharpen because bits of the metal are worn away.

EXPERIMENT 2 - PREDICTION AND RECORDING SHEET

Sample	Predicted order	How much cotton left on surface	Actual order
Sandpaper 1			
Sandpaper 2			
Stone			
Wood 1			
Wood 2			
Glass			

WHOLE CLASS CHART

Sample	Group 1	Group 2	Group 3	Group 4
Sandpaper 1				
Sandpaper 2				
Stone				
Wood 1				
Wood 2				
Glass				

EXPERIMENT 2 - HOW WEIGHT INFLUENCES FRICTION

Materials

- heavy dictionaries
- masking tape
- string
- spring scale
- masonite board
- recording sheet (optional)

Skills

measuring the relationship between weight and friction
recording information in an appropriate manner
inferring how weight affects amount of friction

Background

Friction occurs when two surfaces rub against each other. If there is minimal pressure between the surfaces, then the friction will not be as great as when there is a significant increase in pressure. The greater the pressure between two rubbing surfaces the greater the friction. In later experiments, we will examine ways to reduce the friction while moving the same load. Experiments 3, 4, and 5 can be seen as a mini-section of this unit. This experiment demonstrates the difficulty moving more weight because of increased friction.

Procedure

(a) Using masking tape, attach a string loop to 1 dictionary for each group. Give out the books, the spring scales and the masonite boards.

(b) Have the children pull the book with the spring scale and measure the amount of pull needed to move the book smoothly across the board. This may take a few tries until they can pull without jerking. Do this on both the smooth and the rough side of the masonite board. Record the results.

(c) Do the same thing with 2 more dictionaries on top of the original one. Record the amount of pull.

(d) Repeat, using 2 more books on top.

(continued)

(continued) Experiment 3

(e) Colloquium

- Did it take more pull to move the dictionary on the smooth or rough side of the board? Why?

- Did it take more or less pull to move three books? Five books? Can you explain why?

- Is it easier to pull a light or a heavy person in a wagon?

- How does weight effect friction?

EXPERIMENT 4 - OVERCOMING FRICTION

Materials

- dictionary prepared as in Experiment 3
- spring scale
- masonite board
- round pencils or dowels about 6" long

Skills

measuring the decrease in friction as a result of experimental change

recording the new results and comparing to previous experiment

inferring the nature of the relationship between rolling and sliding friction

Background

I presented this experimant as a problem: "How can you reduce the friction so that less pull will be needed to move the book?" They could use any materials in the room to try and make it easier. They tried marbles on tracks (from Multi-Rollway Game), round dowels which were used for beating rhythms, small carts and wheels from Lego and other things. If these kinds of things are available, pose this type of problem, if not do it as a straightforward experiment. Either way, the children will discover that rolling friction is less than sliding friction by working with a simple roller mechanism.

Procedure

(a) As an experiment, this is fairly basic. The problem is the same as in Experiment 3 only the children can use dowels under the book to make it easier. Let them devise their own ways to use the dowels.

(b) Record the results for 1 book on both surfaces. Then try 3 and 5 books. Look at the differences from Experiment 3. Use the spring scale to measure the pull.

(c) Colloquium

- Did the dowels make it easier or harder?
- Was it still harder to pull 3 or 5 books?
- Did the different surfaces matter this time?
- What do the rollers act like?
- Can you think of any other things that move in a similar manner?

(continued)

(continued) Experiment 4

(d) Extensions

- There are a large number of ways to build small cars using spools or washers as wheels. Also, children can bring in matchbox cars and a variety of experiments using the masonite board as a ramp can be designed.

- If you are interested in working with cars, there is a good set of activities in Slips and Slides called blocks, wheel and hills.

(e) Sample Colloquium

These are selected responses in a discussion following Experiment 4. How can you reduce the friction so the book can slide more easily?

Q. Why did you use marbles and tracks?

A. Marbles really roll fast if you push them and you pull them, if you have something to pull them with. So use a track so the marbles wouldn't roll off and you put the book on it and we needed many more marbles.

A. We could get a bigger track and the marbles wouldn't come off and they'd keep on rolling with the book.

A. Well I was thinking that people slip on marbles so why shouldn't a book slip on them.

Q. What problem did you have when the book slid?

A. The wheels weren't turning as easily and as loosely.

A. When the book was on this it made it a little heavy to pull.

A. I think we had too much weight.

Q. What are some other ways you could think of to make the book slide easier?

A. Go-cart motor on it if they made it small enough

A. Tracks that have big marbles.

A. They have them. In the supermarkets they have boxes on top of rollers and you push it and the rollers go around and it goes outside.

A. By winding up a spring that would turn a wheel.

A. If there were water there you could put a rubber band on two nails with a little paddle and wind it up.

A. Grease!

A. Grease and oil

A. Sand the table

A. Wax the table

A. Soap!

A. Oil!

A. Ice! A. Butter

A. Banana peels!

A. At home when you dust if you put too much dust stuff on the table it gets slippery.

A. When my mom used to wax our tables we'd get on the tables and slide.

EXPERIMENT 5 - BALL BEARINGS

Materials

- coffee can lids with rims
- marbles
- dictionaries
- spring scales

Skills

Same as Experiment 4

Background

Like rollers, ball bearings are helpful in overcoming friction. They create rolling friction and distribute the weight over a number of surfaces.

This experiment can also be posed as a problem: "Given the materials, how can you move the book across the table with the least amount of friction."

Marbles can be used to roll the book in the same way that rollers or wheels were used in the previous experiment. They act like ball bearings in a wheel or a lazy susan.

Procedure

(a) Try to push a dictionary across a table. Then take the coffee can lid, put it on top of a handful of marbles, place the book on the top of the lid and try to slide it across the table. Try it with different amounts of marbles. Measure the pull needed with a spring scale.

(b) Colloquium

- Why did the book move more easily the second time?
- How is this like the previous experiment?
- Does the number of marbles make a difference in how easily the book moved?
- What number of marbles worked best?

(c) Extensions

- Look at a roller skate wheel. Try to get a beginner's skate (only has an axle) and a ball bearing skate. Spin the wheels and see which one lasts longer. Oil one ball bearing wheel and don't oil the other. Spin again and see which continues longer.

- A lazy susan operates on a similar principal. Build a laxy susan by putting a small jar lid inside a larger one. Fill the space between the rims with marbles. Turn it over and watch it spin.

EXPERIMENT 6 - TOO LITTLE FRICTION

Materials

- mayonnaise jars with covers
- soap
- water
- eraser
- oil
- smooth glass surface or mirror

Skills

measuring the effect that lubricants have on friction
defining the relationship between lubrication and amount of friction

Background

Without friction you could not walk on the ground because your feet would skid. Nails and screws would pull out of wood; ropes would slip; tires would spin but the car wouldn't move. The world would literally come to a halt. These experiments show what kinds of problems you might have if there were little or no friction in the world. There are, however, many valuable uses that lubricants have in our everyday life. Without them, machines would wear out much too quickly!

Procedure -- 2 Experiments

(a) Make sure that the jars are left on the table because they could slip and break. In turn, have each child soap up their hands and try to twist the top off the mayonnaise jar.

(b) Rub an eraser across the glass surface and note the amount of friction. Then spread a thin layer of oil across the surface and try the other end of the eraser. Note the difference. Wipe the surface and the erasers clean.

(c) Colloquium

- What happened when you tried to open the jar?
- Why were you unable to turn the top?
- How was the eraser experiment like the jar experiment?
- What situations did the eraser experiment remind you of?
- What happens to a surface if you put oil on it.

(d) Extensions

- Try to walk on a newly waxed floor or across an icy pond. Why can't you get any traction?

- Grease a large nail with vaseline or oil. Hammer it and another one like it but ungreased into a board. Is it easier or harder to pull out the greased nail?

(continued)

(continued) Experiment 6

- Rub two pieces of sandpaper together. Then put grease on the papers. What happens? (The grease fills up the uneveness, making the paper much smoother.)

- Other helpful uses for lubricants: oil a squeaky hinge, soap a sticky window frame, oil a bike wheel

EXPERIMENT 7 - FRICTION SLOWS THINGS DOWN

Materials

- outdoors - playground
- small piece cardboard - approx. 2' x 2'
- large sheet of cardboard - approx. 3' x 4'

Skills

observing the relationship between surface area and friction

defining that relationship based on the outcome of this experiment

Background

When you run through the air, you meet with resistance. If you were able to run in a vacuum, you would be much faster. Trying to run through water which is shoulder-high is the other extreme. The surface of your body rubs against the molecules of air, creating friction. If you increase the surface area, you increase the friction.

Jet planes and rockets move so quickly that unless they are well designed, heat from friction will burn them up. (e.g. meteor entering earth's atmosphere)

In this experiment children will see how the friction from the air can slow them down.

Procedure

(a) In turn, have each child run about 25 yards holding the small piece of cardboard in front of them like a shield. Then have them run with the large piece. Note the difference.

(b) Have races with a fast child using the large cardboard piece versus a slower child using the smaller piece.

(c) Colloquium

- Was it easier or harder to run with the larger piece?
- What was the problem you had?
- What were the results of the race? Did you expect those results?
- Why can't you run as quickly with the large piece of cardboard?
- Do you think that air can slow you down?
- Does air have friction?

(d) Extensions

- Roll a marble down a ramp onto the floor. Measure how far it went. Then roll it on to a rug and measure the distance traveled. Why didn't it go as far on the rug?
- Is it easier to roller skate on cement, a rug or grass?
- Push a block of wood and an ice cub across a table. Which slides further? Why?

EXPERIMENT 8 - FRICTION PRODUCES HEAT

Materials

- wooden kitchen matches (not safety matches)
- mirror or glass surface
- masonit board
- smooth wood
- rough wood
- brick or rough stone
- prediction sheet (optional)

Skills

classifying surfaces by the texture and friction potential

predicting which surfaces will have enough frictin to light the match

Background

The key experiment in this group will require careful supervision. If this is not possible, then do it as a demonstration.

Friction produces heat. The hot senaation from a "rope burn" is just that, a burn. Matches light because of the heat produced. It reaches the temperature where the substances on the match will ignite. Sparks that you see from pieces of metal are the result of friction heating tiny fragments of metal to the burning point.

Children can produce heat from friction simply by rubbing their hands. This principle can be generalized to explain why matches light, car tires become hot, etc.

Procedure

(a) Ask the children to rub their hands together very briskly. Then have them rub their clothing with the palm of their hand. Ask why they think their hands feel hot.

(b) Ask the children to predict whether the match will light when struck against each of the surfaces provided. Try a new match on each surface and record which ones work. Compare to the predictions.

(c) Colloquium

- Based on the hands experiment, why do you think the match would light on some surfaces but not on others?
- What did you already know about the friction of the surfaces you tested?
- Did any of the results surprise you?
- What other ways can you use friction to generate heat?

(d) Extensions

- Saw rapidly through a piece of wood. Carefully touch the saw blade. What do you feel?
- Pump a hand bike pump quickly and then feel the cylinder.
- Light a cigarette lighter. What causes the spark? (Friction heats a piece of flint to its burning point)
- Why do book matches and safety matches only light when struck against special surfaces?
- In cold weather you rub yourself to get warm.

EXPERIMENT 9 - AIR REDUCES FRICTION - DEMONSTRATION

Materials

- aluminum pie plate
- electric hair dryer or blower
- knife

Skills

observing the change that air makes in sliding

predicting what effect the stream of air will have

Background

A layer of air has very little friction. If we can move things about on a layer of air we will meet little resistance. This is the principle involved in hovercrafts and the popular game of air hockey.

Procedure

(a) Before doing this experiment ask the children what they think the results will be.

Cut a hole in the center of the pie plate just a bit larger than the nozzle of the hair dryer. Put the plate upsidedown on a table. Stick the nozzle of the dryer through the hole and turn it on. The pie plate will rise a bit and move easily on a thin air layer. Move it around the table for a while, then turn off the blower and try to move it. Compare the two.

(b) Colloquium

- Why did the pie plate move more easily with the air blower on? Why didn't the plate blow away?
- Where did the air go?
- Why do you think air is so slippery?

EXPERIMENT 10 - FRICTION PRODUCES STATIC ELECTRICITY

Materials

- balloons
- woolen cloth or fur
- string

Skills

observing the changes that occur when friction is introduced into a system

inferring the effect that friction had on the system

formulating a hypothesis about two seemingly contradictory results

Background

When you rub your shoes across a rug on a cold day, the friction creates a special kind of electricity. If you touch a metal door handle, the electricity jumps from you to the metal. In addition, static electricity can be used to make things stick or repel.

In these two experiments, children will rpoduce static electricity which results in two contrasting outcomes. A balloon will stick to the wall when charged, yet two balloons will repel each other. This is because "like" charges repel and the two balloons are charged alike.

Procedure

(a) Blow up a balloon. Place it against the wall and see if it sticks.

(b) Next rub the balloon rapidly with a piece of woolen cloth. Place the balloon against the wall and see if it sticks.

(c) Blow up two balloons and tie a string to each. Hold both strings so that both balloons hang down and touch each other.

(d) Now rub the two balloons with the cloth and try again. Observe what happens.

(e) Colloquium

- Why didn't the first balloon stick to the wall?
- What change took place so that it would stick?
- Does the balloon feel different after it is rubbed?
- What does it feel like?
- How did rubbing the 2 balloons change what happened?
- Why did they behave the way they did?
- Where does friction come into this system?

(f) Extensions

Put some pieces of tissue into a low, clear plastic box. Close the cover and rub your fingers across the top. What happens to the tissue?

Run a comb through recently washed hair. Hold it near the person's head. What happens to the hair?

EXPERIMENT 11 - FRICTION BLOCKS

Materials

- wood blocks - 4" x 6"
- felt or wool
- rubber bands
- thumb tacks
- old bike or car inner tube
- masonite boards
- sandpaper

Skills

observing the relationship of type of surface to amount of friction.

predicting which surfaces will have most and least friction

recording the outcomes of various testing in chart form

controlling variables - holding all except one variable constant

formulating hypothesis about which blocks will slide quickest in relation to each other

interpreting the results of the initial experiment to support further experiments

Background

The friction blocks offer the greatest variety and opportunity to explore different aspects of friction. The first experiment gives the children the information they need to go on and solve many of the problems offered in the extensions. These can be exciting and challenging. Slips & Slides (ESS) offers additional information on using the friction blocks if you wish to go beyond the ideas outlined here.

Procedure

(a) The materials for this experiment are best prepared in advance, however, they can be done by each group if desired. You will need five wood blocks per group. Leave one plain, put three rubber bands around the second, put four tacks (one per corner) in the third, glue or staple a piece of cloth on the bottom of the fourth, glue or staple a strip of inner tube on the fifth, and sandpaper on the sixth. Give out the blocks and boards to each group.

(b) Before any experimenting is done, have each group predict the order that the different blocks will slide down the smooth and rough surfaces. (use the prediction sheet enclosed or your own version)

(c) Now test the blocks to find out the actual order in which they will slide. This can be done by raising the board till the blocks begin to slide and continuing until all the blocks are down or simply putting a yardstick across the front of the blocks, lifting the board fairly high and then releasing the yardstick. Do these tests on both sides of the board and record the results.

(continued)

(continued) Experiment 11

(d) Colloquium

- Were the results on both surfaces the same?
- Which blocks were the fatest? The slowest?
- Did each group get the same result?
- Why or why not?
- Were any groups able to predict the outcomes?
- What was the difference between the two tests?
- Why do you think this was true?

- What do you know about each of the blocks?
- Which materials have the most friction? Least?
- Why are some more slippery than others?
- What is grip? Traction?

(e) Extensions and further problems using friction blocks

These problems are listed in no special order, but provide a chance to further explore the characteristics of the friction blocks. They can be done as individual projects, special demonstrations or whole class experiments.

- Put any 4 blocks on the board so they make a train. Can you make a train that:
  - stays together when it moves?
  - separates just the first car? (Runaway engine)
  - has a caboose that is too slow? (Loose caboose)
  - splits in half?
  - all cars separate?

- Stack 4 blocks on the board. Can you arrange them so the pile falls before it begins to slip? So that it slides and doesn't fall?

- Put two blocks with rubber surfaces on the board. Put a thumb-tack block behind one. Will they both slide at the same time and same speed?

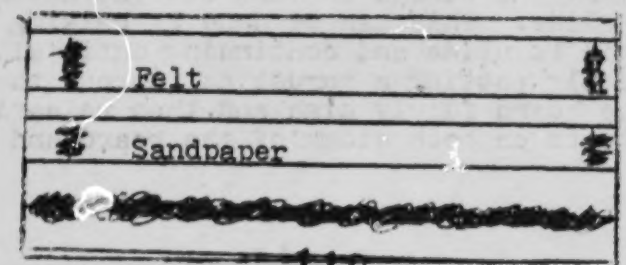
- Put a plain block on top of a rubber block. Test this against a rubber block

- Can you make a train on the rough side which is faster than a train on the smooth side?

- What is the fastest train you can make? What is the slowest?

- Predict how high you must lift the board for each block to slide. Measure with a yardstick to see how close you came. Try this for both sides of the board.

- Take an extra board or two and put a strip of felt or cloth (about 6" wide) along its length. Also put sandpaper in a similar fashion.



(continued)

(continued) Experiment 11

- Use this board to race the blocks, trying to "give a lead" to different blocks in order to make them finish at the same time. This will be extremely challenging!!

- Test sandpaper on sandpaper versus felt on felt. Try other combinations.

(continued)

(continued) Experiment 11

Name_____ Date_____

PREDICTION AND RECORDING CHART FOR SLIPPERINESS

Block	Predicted order		Test 1 (smooth)	Test 2 (rough)
	smooth	rough		
Plain Wood				
Elastic Bands				
Thumb Tacks				
Cloth or Felt				
Tire Rubber				
Sandpaper				

Were the results of Test 1 the same as your prediction? _____

Were the results of Test 2 what you predicted? _____

Were the results of Test 1 and Test 2 the same?_____

Why or why not?_____

_____

_____

_____

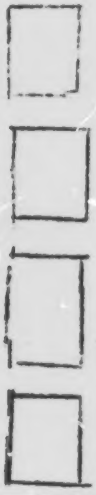
(continued)

(continued) Experiment 11

Name_____ Date_____

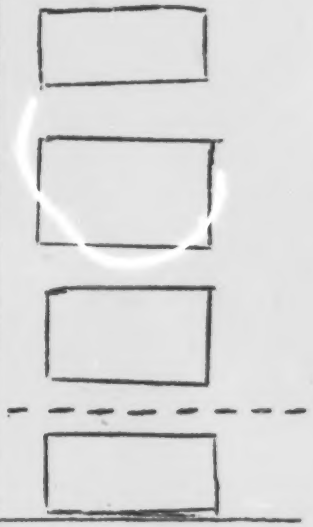
FRICTION TRAINS

Fastest Train

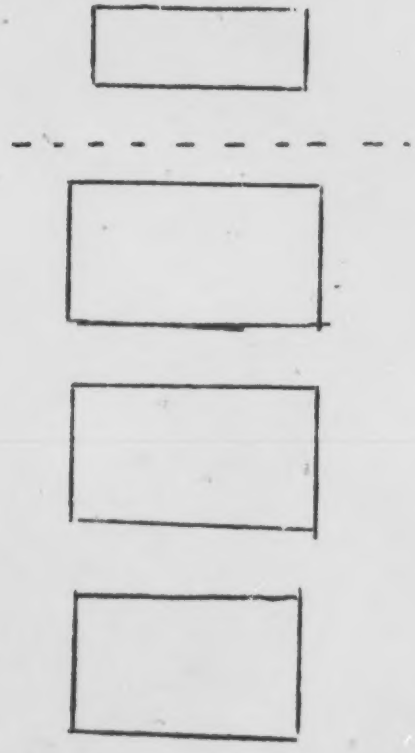


Slowest Train

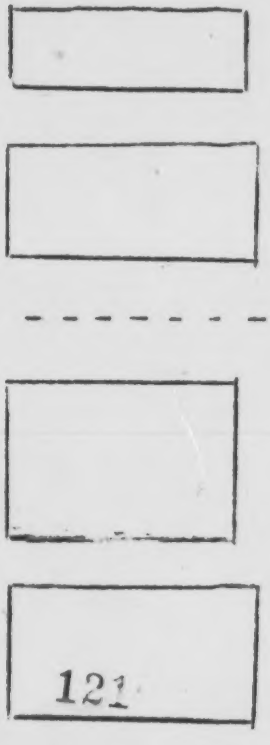
Loose Caboose



Runaway Engine



Split in two



SOLUTIONS
AND
CRYSTALS

Brendan O'Shea

July 1976

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OVERVIEW OF UNIT

I have prepared these lessons as a continuation of the ESS unit on Mystery Powders. I have attempted to avoid any bias toward either the teacher-oriented or the pupil-discovery method; rather, I have included as much detail as possible in hopes that you will select and modify my suggestions according to your own preferences.

MATERIALS LIST

Chemicals

Various chemicals, including salt, sugar, alum, epsom salts, Rochelle Salt, sodium bromate, sodium chlorate, chrome alum, washing soda, MSG

Other Supplies

Plastic pill vials
test tubes - clothespins for holders
mason jars
assorted jars - wide mouthed
hand lenses
microscopes
aprons
measuring spoons
potholders
eye droppers
tweezers
shallow dishes
nylon thread
paper clips
hot plates, or elec. coffee percolator
cover slips
liquid glue (LePage's)
Krylon plastic spray
Measuring containers - pyrex is best
measuring spoons

RESOURCE LIST

At Museum of Science:

Board of Education, Hamilton, Ontario, Crystals
Kingston, Ont., Donco Press

Carona, Philip B. Crystals. Chicago, Follett Press; 1971

Freeman, Mae and Ira. Fun with Chemistry. New York: Random House, 1964

Hennessy, David E. Elementary Teacher's Classroom Science Demonstrations and Activities. Englewood Cliffs, N. J. : Prentice-Hall, 1964

In Acton:

ESS, Small Things. St. Louis: McGraw-Hill, 1967

Holden, Alan and Singer, Phyllis, Crystals and Crystal Growing Garden City, N. Y.: Doubleday & Co., 1960 -(see Gene Trainor)

Morgan, Alfredl First Chemistry Book for Boys and Girls. New York: Charles Scribner's Sons, 1950

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"Chemical Changes Around Us"

PLANNING FOR THE UNIT

I should mention here a few of the problems you might encounter when using this unit with third graders. You may want to forewarn or instruct your class in dealing with some of them; others you might try to solve on your own.

There is an element of personal safety involved in the use of hot plates to warm certain solutions. I think that the children, while certainly having the notion that a heated object can be dangerous, will need a lot of direction and support in order to apply this notion in a busy classroom. You will have to be quite thorough in outlining a general policy of hot plate usage so that there will be no burns. I also think that long aprons worn over pants and long-sleeved shirts ought to be the standard uniform for anyone using the hot plates.

The second and more general area of concern involves the chemical reactions that you will encounter. Solutions and crystals behave erratically; you should be prepared for failure especially in your first attempts in crystal growing. If you anticipate these instances (and I assure you that there will be some), you can use them to pose questions to your class as to why they occurred, and what might be done to correct them. You might want to rehearse some of the experiments at home, or you might wish to go into the situations "cold". Either way, you should expect inconsistencies in many of your results.

Keep your proportions moderate. Go too low, and you won't be able to view the solutions properly; go too high, and you'll end up spending all your money on solutes.

Finally, I have written these lessons so that they can be taught to a classroom consisting of any number of teams composed of between three to six students each. Again, please modify this to suit your own needs.

LESSON I:: Transition from Mystery Powders to Solutions and Mixtures

- Objective: To re-acquaint children with the major types of interaction between solids and water

- Skills:

  Observing - Children will observe powders and fluids, and their attendant changes when combined

  Classifying - Children will classify these interactions as follows: solutions, mixtures, or neither

  Measuring - Children will be encouraged to use constant quantities of solid and water

  Recording - Children will complete teacher made data shells

  Predicting - Students will be asked to predict what will happen when various solids are mixed with water. They will also be asked to predict how the solid in a mixture will react differently from the solid in a solution. Stating operational definitions--the students will know the compeonent parts of a solution (solvent and solute), and how that solution behaves in certain circumstances

  Materials - sugar, salt, cornstarch, flour, clean gravel, pails, tumblers, teaspoons, light source, hand lenses, tape

  Content - Display the pails of powders to the class. Each pail should be numbered, and each team should have 5 pails which should be similarly numbered. Ask each team to transfer 1 level teaspoon (or any small amount) into its corresponding tumbler, and encourage them to observe these powders with their hand lenses.

(You should prepare clean gravel by washing it several times so that the dust is rinsed clear. You also might wish to provide an extra pail with dirt so that children might experiment with it.)

After time has been devoted to the observation of powders, the teacher should direct each team to put the same amount of water into each tumbler (½ pint, perhaps) and observe the changes that occur. The students should stir their mixtures, noting what happens both while they stir and after they stop.

(continued)

(continued) Lesson I.

Evaluation:

- Questions you might ask:

  - What happens to the solid when you stir?

  - What happens if you leave the system undisturbed for 5 minutes?

  - What happens when a light source is projected through the system?

I found that the most difficult aspect of the evaluation was in trying to get the students to allow their systems to remain undisturbed for 5 minutes. Otherwise, it was quite easy to get them to distinguish three main categories of systems:

1. clear - no solid left (solution)
2. cloudy - solid drops out gradually (mixture)
3. solid drops out almost immediately (technically still a mixture)

The children tend to us "disappear". I think this is alright, but at this stage I would introduce four new vocabulary words:

solute - the solid which "disappears"

solvent - the liquid into which the solute "disappears"

dissolving - the act of "disappearing"

solution - those systems which are <u>clear</u> (they may be colored), and out of which no solute is seen to drop.

One boy, who was experimenting with his sugar-water solution, noticed the few sugar crystals left at the bottom of his tumbler "melted" when they were held near the light source. You might watch for this, as it provides a good jumping-off point to later lessons involving temperature change in solutions.

The children should fill in a shell chart something along these lines:

(continued)

(continued) Lesson I. Evaluation

Name of solid (solute)	Clear when mixed w/water?	Any solid fall out onto the bottom	Solution or not?

LESSON II.: Strengths of Solutions

- Objective: To discover that solutions can be dilute (weak) or concentrated (strong), and that a given quantity of water at a given temperature can only dissolve a certain amount of solute.

- Skills:

Observing - Children will observe that various solutions can be made using the same solute.

Classifying - Children will classify solutions according to strength.

Measuring - Children will accurately measure water and solute.

Recording - Students will record data numerically and graphically.

Predicting - Students will be asked to predict the maximum amounts of various solutes that can be dissolved in a given amount of water.

Stating operational definitions - The students' working definition of a solution will be refined and limited.

Controlling variables - The children will control the amount of solute in their solutions

Materials - Various powders (sugar, salt, alum, epsom salts), tumblers, stirrers

Content - This lesson should be divided into two parts?

1. Brainstorming and review: Fill two tumblers with "ideally clear" tap water. Ask: Have we dissolved any solute in this water? As far as we know, is it a solution or not?

(continued)

(continued) Lesson II.: Content

Although it is convenient for the purposes of the experiment to label the water as not being a solution, the teacher should point out that it may very well be a solution, with different minerals (and gases) dissolved in it.

Put a few specks of salt in one tumbler. Ask: Is this a solution, according to our definition? Some say yes, others no. Some will want to see the system stirred, but encourage others that stirring is not a prerequisite solubility. Ask: What effect does stirring have? Why does it have that effect?

Put ½ teaspoon of salt into the second tumbler. Stir until dissolved. Ask: Is this a solution? Why or why not?

2. Experiment:

Each team is given a tumbler and asked to do two experiments:

Using exactly ½ pint of lukewarm water (which you have made available in a tub), how much of a given solute can be dissolved? Using a lesser amount of lukewarm water, how much solute can be dissolved?

Encourage the children to add solute slowly.

- Evaluation - Make a line graph for each solute that the children experiment with. From this graph, you will be able to ask children to make predictions about the capacities of, say, larger quantities of water for a certain solute. Bring out the idea of a "saturated" solution to the kids, which is simply a solution holding the apparent maximum amount of dissolved solute at room temperature. Also, explain the term "unsaturated" to them as being any solution weaker than a saturated one.

- Try this experiment for those who insist that stirring is essential:

(continued)

(continued) Lesson II : Evaluation

Take ½ pint water, aand put 1 tbsp. salt in the water. Leave standing, but do not sir. What happens? Is there a solution? Can you prove it?

The children will be interested in finding out where the solid goes once it has dissolved, and you should anticipate this interest by posing this question to them. If I had a solution of salt, can I get the salt back? How? Has the salt disappeared for good? Discuss evaporation, and leave several solutions overnight in shallow dishes and see what remains.

LESSON III.: The Relationship of Temperature and Solubility

- Objective - To determine the relative importance of temperature on the solubility of a given solute and water.

- Skills:

Observing - Students will determine precisely when certain systems become solutinns at various temperatures.

Measuring - Students will accurately measure solvent and solute, and they will note exact temperature readings.

Recording - Students will record data graphically.

Predicting - Students will be asked to predict the solubility of a given solute and water at various temperatures.

Stating operational definitions - Students will learn the general variations in solubility that come with changes in temperature.

Controlling variables - The students will control the temperature and observe its effect on different solutions.

Materials - heat sources, tumblers and pyrex containers, potholders, ice water, sugar, alum, and salt.

Content -

Note: In this lesson, as in other lessons in which you are heating solutions, keep the volume of water way down. For example, if one team heats 2 cups of water to the boiling point, and then dissolves as much sugar as possible, you've just used up about 16 cups of sugar! So--be careful!* Also, you should set up several large evaporation pans (one for as many solutes as you are using in this unit) whereby you

(continued)

(continued) Lesson III.: Content

can recover the various solids that the children have been sissolving.

* See the crystal-growing lessons for ratios of solute to water for solutions at the boiling point.

The children of each team should be given a particular solute: washing soda, epsom salts, table salt, sugar, or monosodium glutamate. Each team should fill one tumbler with cold water and another with warm water, both of which you have provided in tubs for them. They should keep the quantities the same (I recommend ¼ to ½ cup), and take an accurate temperature reading. They should then slowly add their solute, seeing how much each water system will hold. Have them record their data numerically, and on a line graph. Ask them to make a prediction about how much of their solute will dissolve if the solution is warmed to 150°. Ask them to measure the same amount of water into a pyrex vessel or saucepan, heat it to 150°, and determine how much solute can be added to one solution.

- Evaluation - Questions you might ask:
  - As you heated the solutions, did the solute burn away?
  - Did it dissolve?
  - Are boiling and stirring similar in any way?
  - Are all solutes affected equally by temperature change?
  - What might you do if you wanted to dissolve a cup of sugar in a cup of water as fast as possible? Can you think of two things?

Lesson III.: TEST -

Distribute papers to the kids. Have them number from 1 to 6. On a table before you, have 8 tumblers labelled, each half-filled.

1. Put a few specks of sugar into tumbler #1, stir, and describe what you are doing. Ask: Is this a solution? Write YES or NO on you paper.

2. Put a teaspoonful of sugar into tumbler #2, stir, and describe. Ask: Is this a solution? Write YES or NO.

3. Put a teaspoonful of dirt into tumbler #3, stir, and describe. Ask: Is this a solution? Write YES or NO.

4. Put a teaspoonful of flour into tumbler #4, stir, and describe. Ask: Is this a solution? Write YES or NO.

5. Take tumber #5, put ½ teaspoonful of salt into it, stir, and describe. Take tumbler #6, put 1 teaspoonful of salt into it, stir, and describe. Ask: Which solution is stronger? Write either "5" or "6".

6. Take tumbler #7, which is filled with ice water, and tumbler #8, which is filled with lukewarm water. Ask: Which tumbler will hold more water? Write either "7" or "8".

LESSON IV.: <u>The Relationship Between the Strength of a Solution, its Boiling Point, and its Ability to Boil</u>

- Objective: To note what changes, if any, the addition of a solute exerts on the ability of water to boil.
- <u>Skills</u>:

Observing - Students will observe the boiling of solutions of varying strengths.

Classifying - Students will classify these solutions by their ability to boil.

Measuring - Students will measure solvent and solute so as to create solutions of different strengths.

Recording - Students will record their data numerically and graphically.

Predicting - Using experimental data, students will be able to make predictions about the freezing points of other solutions.

Stating operational definitions - Students will formulate a more exact definition of boiling.

Controlling variables - The students will vary amount of solute in each solution. They will also employ a control component.

Materials - Pyrex containers or saucepans, measuring cups, heat sources, various solutes, thermometers.

Content - Each team will prepare two or three solutions of the same volume but with varying strength, plus a control using only tap water. Again, plan to have the water available in a large pail so that there will be continuity among the experiments and allow the heating sources to warm up fully before warming the solutions. Also, advise the students against adding too much solute. A small variation should produce the desired effect.

(continued)

(continued) Lesson IV.: Content

You are going for two major objectives here---the changes in a solution's boiling point and in its boiling rate so you should have thermometers and at least one clock with a sweep second hand available. The degree of teacher directivity toward these goals is entirely up to you.

- Evaluation - Have students chart a line graph for their particular solute, and combine all of the line graphs on a classroom graph that you might tape to the blackboard. There can be two types of graphs: one charting boiling points, the other, boiling rates.

Questions: What is boiling? When bubbles first occur? When water is bubbling rapidly? Is boiling more a factor of temperature, or of molecular action? What substances do we know that boil at different temps? Ask if they have ever made fudge at home.

Once these questions have been discussed, you should move to the effect of a solute on boiling. Are there some solutes which affect boiling more than others? Encourage them to make predictions about freezing.

LESSON IVA.: <u>The Relationship Between the Strength of a Solution, its Freezing Point, and its Ability to Freeze</u>

- Objective: To note what changes, if any, the addition of a solute exerts on the ability of water to freeze. This is a companion to Lesson V.
- Skills:

Observing - Students will observe the freezing of solutions of various strengths, and will examine ice crystals microscopically.

Classifying - Students will classify these solutions by their ability to boil.

Measuring - Students will measure solvent and solute so as to creat solutions of different strengths.

Recording - Students will record their data numerically and graphically.

Stating operational definitions - Students will formulate a more exact definition of freezing.

Controlling variables - The students will vary the amount of solute in each solution. They will also employ a control component.

Formulating hypotheses - The students will hypothesize about the general effects of temperature on boiling and freezing.

Materials - Solutes from Lesson IV., plastic ice trays, measuring cups and spoons, thermometers

Content: As in the previous lesson, the students will prepare two or three solutions of varying strengths, all using the same solute, plus a control of tap water. Have the students pour these solutions into plastic ice trays. Make sure that each compartment is labeled, and that all compartments are filled to the same level. Leave the trays in the freezer of your school cafeteria, or have the students do the experiments at home. Provide thermometers to see if the

(continued)

(continued) Lesson IVA.: Content

freezing point is appreciably altered. You should check the solutions every 15 minutes or so.

- Evaluation - Have students chart a line graph for their particular solute, and, as in Lesson IV, you may combine them onto one large graph in front of the class.

You will be asking questions that correspond to those which you posed in the preceding lesson:

- What is freezing?
- How can we tell if something is frozen solid?
- Can we agree on a suitable definition?
- And, does strength have an effect on freezing?
- Do we see any correlation between the effect of a solute on boiling and freezing?

LESSON V.: The Relationship between the Type of Solute and the Boiling of its Solution

LESSON VA.: The Relationship between the Type of Solute and the Freezing of its Solution

These are companion lessons, to be dealt with in much the same way as Lessons IV and IVA. Simply keep the quantities of solvent and solute constant, but vary the types of solute in an effort to determine whether this affects freezing and boiling.

Homework assignements:

(1) At the close of school, give each student a vial of epsom salt - sand mixture. For homework, the student must bring back only the epsom salts.

(2) Give each child, or team, a sample of an unknown solute. Have them prepare a line graph showing the effect that different amounts of the solute have on the freezing of one cup of water. Remind the children to use plastic containers. Supply graph paper, or line graph shells.

LESSON VI.: Observation of Microscopic Crystals-discussion and observation

Lead the class in a general discussion of crystals. For several days before, gather samples of crystals that the children might observe: large crystals that you might find embedded in rock, or that you could purchase from a hobby store or borrow from a science laboratory or a museum; and samples of pulverized rock that will yeld a bounty of crystals when observed under a microscope. Crystals may be found in the kitchen as well, and children will enjoy observing and classifying such common household items as sugar,salt, borax detergent, epsom salt, drano, etc. Also, have the children observe solids that are not crystals: dirt, flour, cornstarch and see if the children can formulate any gerneral definition of crystals.

Winter - kids will love snow crystals:leave slides, scope and and a can of hair spray outside, and allow them to cool. Catch flakes and spray them from a distance with gentle mist. Bring indoors when dried.

Other ideas - Catch flakes on black velvet or felt. Transfer to cold slide. Set in place using 1 drop of the following mixture: 99% acetone
1% Formvar (see Gene Trainor)

LESSON VII.: Observation of Crystals - evaporation

- Objective - To promote children's awareness that crystals may be recovered from a solution through evaporation, and that evaporation occurrs at different rates.

- Skills:

Observing - Students will observe solutions and controls at various stages of evaporation

Classifying - Students will classify crystals by shape and color

Measuring - Students will measure solvent and solute so as to make nearly saturated solutions

Recording - Students will record data pictorially

Stating operational definitions - Children

Interpreting data

Materials - Various crystals (sugar, salt, alum, epsom salts), pails, test ube, shallow dishes, microscopes and hand lenses, slides, droppers

Procedure - Have the prepare one pint of saturated solution for each solute that you have. Have them transfer one drop of each solution to a slide, and encourage them to observe it for 5 minutes under a microscope. Questions--What changes took place in the drop? Does your finished product look the same as the powder that you used at the beginning of the experiment to amke the solution? Have the students place 40 drops of a solution in a shallow dish, and 40 drops in a test tube. Questions--Which will evaporate first? Will there be any difference in the shape of the crystals?

Demonstration: You'll need an overhead projector, a few transparencies, and some LePage's glue.

(continued)

(continued) Lesson VII.: Demonstration

Take a small amount of water and heat to boiling. Add epsom salts until the solution is saturated. Stir in one or two drops of LePage's glue, let it dissolve, and brush the mixture onto the transparencies. View it for a few minutes. Crystals should start to grow.

This can be a beautiful demonstration. Try it with different crystals, and use food coloring if you like. Also, try with iodine. What shape are the crystals? Breathe on them a few times. What change is there? What caused the change?

Further areas for study:

Q. Can you tell if a crystal grows from its outside or inside? Is crystallization anything like the freezing of water? What happens when you heat these crystals again? Can you make another solution using crystals already recovered by evaporation?

Lesson VIII.: Growing Crystal "Colonies"

The children may have observed material dropping out of a cooled solution in the preceding exercises, especially 6 & 7. If so, draw the children's attention back to these occurrences, since this is crystallization, although in a form too rapid and random to form large crystals.

If the children have not observed this occurrence, or if you would like to make sure that they have an adequate introduction to the topic, go back one step and have each group prepare a saturated solution of alum, epsom salt, sugar or sodium nitrate. * Ratios of solute to water will be found at the end of this lesson. Ask them to take care to try to dissolve just a hair above maxium amount of solute, but no more. Once the groups have their staturated solutions ready, ask:

Q. If we do not add any water, how might we change these solutions so that it is possible to dissolve more solute in them? The students should hopefully remember the relationships between temperature and solubility (experiment 5), and they should suggest that the solutions be heated. If not, you'll have to lead them back a bit further--use your own judgement.

Have the students transfer the solutions to pyrex containers, and let each group heat their solution.

Q. What has happened to the undissolved solute at the bottom of your containers when you began to heat it? Where did it go? Is it still "in" there? Could we get it back in solid form if we wanted? How?

It is not necessary to have the children heat their solutions all the way to the boiling point. As long as they have heated them (160°-180°F) so as to allow for the dissolving of more solute, they should obtain crystallization later. After this is done, the students should remove the solutions from the heating source.

Q. How can we "pull" the solute out of this solution? Can

(continued)

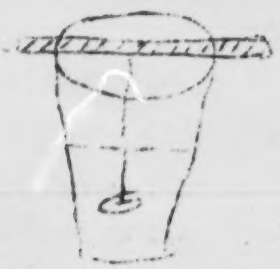
(continued) Lesson VIII.: Growing Crystal "Colonies"

we do it by evaporation? Can we do it wouthout evaporating the water? How? Present to the class the solubility graph that was prepared in Lesson III.

Q. Assuming that evaporation is a reduction of the solvent, what other variables in the solution can we change? The children should suggest (1) temperature - the graph should tell them; (2) the amount of solute - someone might suggest it. A change in either or both of them may cause precipitation, so they should both be explored.

Q. What happened when you heated your solutions? Did the solutes remain, or did they dissolve? If you continued to heat them, would the solute repappear before full evaporation took place? Some students may wish to try this. Others should be encouraged to try slowly cooling the solution, and adding a grain of "seed" solute to start off crystallization.

It is relatively easy to grow a large number of crystals from a given solution as follows: Boil water and dissolve as much solute as possible in it. Pour the solution into jars, and suspend a paper clip from a thread and hang one into each jar. Use a pencil for hanging the clip. The set-up should look like this:



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(continued) Lesson VIII.: Growing Crystal "Colonies"

As the solutions cool, you will find many crystals growing on the paper clip and thread. This is a good introductory method for crystal growing, and the children will enjoy it, but if you would like to grow large, single crystals you will need to employ the directions in the next lesson.

SAMPLE PROPORTIONS FOR GROWING CRYSTAL "COLONIES"

Substance	Amount of Solute	Amount of boiling water
Washing soda	4 tbsp.	10 tbsp.
Epsom salts	8 tbsp.	4 tbsp.
Monosodium glutamate	4 tbsp.	4 tbsp.
Table salt	8 tbsp.	4 tbsp.
Cream of tartar	1 tsp.	12 tbsp.

LESSON IX.: Growing Single Crystals

- Objective - To promote children's awareness that crystals may occur within a solution, and to allow them to grow such crystals

- Skills:

Observing - Children will observe the behavior of solutions and the growth of crystals over an extended time.

Classifying - Children will classify crystals by color, shape, and size.

Measuring - Children will be encouraged to use constant quantities of solvent and solute.

Recording - Children will record data by drawing

Materials - glass jars with lids, thread, large quantities of solutes;(alum, Rochelle salt, sugar, Epsom salts, table salt, etc.)

Procedure - I will employ the evaporation method, which involves suspending a small crystal in a saturated solution and allowing evaporation to occur. As this happens, the solution will become supersaturated. Instead of precipitating, the excess solute should crystallize around the suspended "seed".

Preparing a saturated solution

Preparing a saturated solution is best done by withdrawing solid from a super-saturated solution until the system reaches equilibrium. What you will do is:

1. Add a given quantity of solute to a given volume of water. (See table below)
2. Heat unitl all the solute has dissolved. Do not use aluminum containers, and keep the lid on while heating, if possible.
3. Allow the solution to cool to the temperature at which

(continued)

(continued) Lesson IX.: Preparing a saturated solution

you expect to grow crystals. (The solution is now supersaturated).

4. Seed the solution with a pinch of the solute. The excess solute will crystallize around it.
5. Seal the jar for 2 days. Shake it well twice a day.
6. When the precipitate stops growing, the solution has reached its saturation point.
7. Pour off the saturated solution into another jar, taking care to exclude as much precipitate as possible.
8. Scrape the deposited solute onto a plate. When dry, you may return it to the original supply.
9. Wash and dry the first jar, pour the saturated solution back into it, and seal it, since further evaporation would cause the solution to become supersaturated.

Growing and Mounting Crystal Seeds

An easy way to grow crystals is by pouring one ounce of the saturated solution into a glass and setting it in an undisturbed place. As the solution evaporates, some crystals should be deposited on the bottom of the glass. If this does not happen, add a very small amount of crystalline powder. Harvest the seeds with a tweezer when they are more than ¼ inch long, set them on a piece of tissue and dry them well.

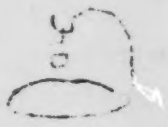
Then, wash and dry your hands carefully, for they contain numerous seeds that are invisible. Make a loop or slipknot in a piece of thread and tie it arount the largest crystal seed. Set it aside. Get a piece of wire and bend it into a "cobra" shape that will fit into the jar in which you are planning to grow the crystals. The cobra will look something like this:

(It is important not to make it too tall, because you will have to keep it constantly covered with solution so as to prevent any crystallization along its surface.

(continued)

(continued) Lesson IX.: Growing and Mounting Crystal Seeds

Tie the thread and crystal to the top of the cobra, so that the seed is suspended in mid-air, like this:



Growing the Crystal

Place the "cobra" in the jar of warm solution and cover the top with a cloth held in place with a rubber band. This will facilitate evaporation, yet it will prevent dust from dropping into the solution.

During growth, do not disturb the crystal. Set it in an out-of-the-way place, and also try to keep the temperature constant by using towels or thermal ballast. Make sure that the level of solution is always above the level of the cobra. It it falls dangerously close, you may add more solution, as long as it is of the same strength as your original solution--that is to say, saturated.

Crystals do not grow well by this method after they have reached a diameter of one to one and a half inches(1to 1½inches) across, so you should harvest them before they reach this size. Upon taking a crystal out of solution, you should dry it immediately and spray it with Krylon in order to preserve it. Otherwise, repeated handling plus exposure to air will cause it to deteriorate.

Crystal "recipes"

In this section you will find examples to make the preceding narrative clear. To begin with, let me quote from Crystals and Crystal Growing, by Holden and Singer

An Example of a Recipe

....The recipe is for growing a crystal of Rochelle salt....

I. Supersaturated solution
   a. 1 pound Rochelle salt in 349 cc (11.5 oz) water
   b. 130 grams Rochelle salt per 100 cc. water....

(continued)

(continued) Lesson IX. Crystal "recipes"

The "a" quantities are based on your buying a certain quantity of the salt. They alway specify the smallest amount of salt that will give satisfactory results,....

The "b" quantities are ratios; from them you can calculate any desired quantity of solution.

To grow a Rochelle Salt Crystal, dissolve one pound of the salt in 349cc of water...or 11½ ounces of water... Heat the mixture to dissolve the salt, seal it in a Mason jar, and let it cool. Then add some grains of Rochelle Salt; the supersaturated solution will deposit its excess on the added grains, and in a couple of days the solution will become saturated. Pour off the solution, and grow some seeds from an ounce of it.

Now you are ready to make the growing solution. To grow by evaporation, warm the saturated solution to dissolve the unwanted seeds then let it cool again.... This is the growing solution in which you plant the seed...

Here are chemical "recipes" given for several common substances that you can obtain from the home, drug store, or science laboratory. In each case, use the quantities given and proceed to grow crystals by the evaporation method. Some tips to keep in mind are:

1. Whenever possible, use distilled water or rainwater.
2. Remember that large crystals tend to dissolve. 2" should be the maximum size for any crystal.
3. Containers should be as clean as possible, both dirt-free and detergent-free.
4. Check for purity of chemicals, especially when using household products. For example, much commerical salt is mixed with cornstarch and will not grow good crystals.
5. The slower the rate of cooling, the better the crystal growth will be: Use towels or thermal baths.

Here, the, are the recipes:

1. Alum, or potash alum
   a. 4 oz. alum in 567 cc (19 oz.) water
   b. 20 grams per 100 cc. water

(continued)

(continued) Lesson IX.: "recipes"

2. Rochelle Salt
   a. 1 pound Rochelle Salt in 349 cc (11.5 oz.) water
   b. 130 grams per 100 cc. water

3. Sodium bromate
   a. 8 oz. sodium bromate in 454 cc (15.4 oz) water
   b. 50 grams per 100 cc. water

4. Sodium chlorate
   a. 1 pound sodium chlorate in 400 cc (13.5 oz)
   b. 113.4 grams ($\frac{1}{4}$ lb) in 100 cc water

5. Chrome alum
   a. 4 oz. chrome alum in 189 cc. (6-2/3oz.) water
   b. 60 grams per 100 cc. water

WEATHER

"With Your Eyes In The Sky, You May Walk Lively
In The Path Of Beauty."

Zini Indians

Joseph McInerney

July, 1976

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MATERIALS (in Kit)

25 thermometers (ECHO)
4 Sargent-Welch Thermometers (Cat. No. S800 35 BF
(2.75 each - 10% discount per doz.)
empty wide mouth jar
matches
Cobalt Chloride crystals (Sargent-Welch 1lb. $5.75 SC 11503)
test tube
holder
alcohol burner
medicine dropper
candle
2 glass jars
#6,7 & 8 cork stoppers with one hole (several)
red or blue dye
index cards
cardboard disk the size of a record
Polar map of the Northern Hemisphere
air pump (Sargent Welsh No. 1424)
gallon can (duplicator fluid can)
medium sized balloons
comb
light powder or wallpaper paste
glass jar
rubber bands
straws
plastic tubes
mimeral oil
cotton shoestring
cardboard milk cartons
7 narrow boards (2" x 12")
50 wood block bases (4" x 4")
box of straight pins
sewing needles
50 syringe caps

(continued)

(continued) Material (in Kit)

50 3" feathers
50 3" finishing nails
20 (or so) direction compasses
½" diameter dowels cut to 4" lengths
a 50 ml, 100 ml, 250ml and 300 ml flasks
glass straws

MATERIALS (from other sources)

desk lamp
hot plate
kettle
baking pan
aquarium tank
cardboard
turntable
magic markers
helium supply
postcards & stamps
balloons
string & hole punch
small fan
vacuum cleaner
pencils with erasers
small tacks
2" x 3" plastic flaps (Formica tabs)

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OVERVIEW and INTRODUCTION

In 1976 an easy way to draw a crowd on a busy street corner is to stop and look to the sky for a period of time. This simple act of atmospheric observation is so rare that the viewer will be thought either odd or ill, probably both. The upward glance is a scarce thing in a society with heads bowed to material burdens. However, I think most children do not take for granted the daily drama of the sky, the marvels and panorama of weather, the thrill of clouds and wind, the awe of thunder and lightning. They respond alertly to the power of this majestic machine and do not ignore the "path of beauty" that is the sky. But, is it possible for a child to learn something of meteorology without losing this romance for atmospheric phenomena?

I certainly hope so, and this unit on weather is an effort to bridge that gap. I suggest to start with that you post a large chart in your room labled "Experiences" and ask your children to relate experiences they have had regarding weather phenomena, any observations or interesting happenings. List all in brief form, avoiding duplication when possible, with a magic marker and leave the chart posted throughout this unit so you can add to it as time goes on. Next label another chart "Experiments" and briefly record any and all experiemtns the kids suggest and questions they would like explored and/or answered. This list should also stay for the duration of the unit since it will provide something of an activity map for your study of weather. Finally, call one chart "Vocabulary" and tell your class that you will list new words and concepts <u>after</u> they understand and have had experience with them. No smoke screen jargon, but only words and ideas that grow naturally out of the experiences, demonstrations and experiments of the material. This will help demythologize our science teaching and help us take seriously children's statements.

There are many ways to orgainze a study of weather for intermediate grades but all involve elements of observation, recording,

(continued)

(continued) Overview and Introduction

experimenting and predicting. This unit has three major activity sections listed here with their page symbols: (1) demonstrations and table top weather creation, (D); (2) microclimates and "field" experiences, (mc); (3) instrument construction,(i). Rather than present the material in this fashion, however, I have structured the unit around the three major factors that affect weather---TEMPERATURE, MOISTURE, and AIR. This should help you organize your thoughts when trying to put together a theoretical framework for a weather study. The categories are extremely broad and flexible; for instance "Air" includes work on air pressure and tornadoes, wind and water currents. You may decide to do all the microclimate experiements together as a unit and avoid the demonstrations entirely. If so you should have little difficulty locating the appropriate exercises if you look for (mc) and (i).

The best time to study weather is probably during the fall and spring months since they allow for plenty of outdoor experiments and a "sumptuous variety" (Mark Twain) of weather. Ideally this unit should follow a study of air and water pressure, "fluid dynamics", because weather to some degree is a macrocosmic acting out of mircocosmic physical phenomena. It is difficult to talk of air pressure and wind if a child cannot distinguish between air and nothing. The relative depth of your approach to the material will have to be tempered by such considerations. I have tried to take these factors into account and hence included a generous amount of background material in the (D) demonstration and table top weather sections.

Grouping for the microweather experiments should involve no more than five kids per team, ideally four. This allows for all to get involved and participate in the activities and not sit passively back while the more articulate dominate. The colloquium phase of each activity should help you evaluate how the children are interpreting and internalizing the material from the simple to the complex. Their observations here should

(continued)

(continued) Overview and Introduction

help you refine your approach and clarigy the focus of the next lesson. All of the activities included have been done with real children.

A Short Overview of the Microclimate and Instrument Sections...

MICROCLIMATES (mc)

If you are uncomfortable in the direct sunlight you probably feel better if you move into the shade. In so doing you are taking advantage of the fact that weather conditions in the shade (temperature, humidity, air movement) differ from those in the sum. Sometimes measurably different conditions exist within a few feet of each other and are called microclimates or little weather areas. They have characteristics which can be detected even using simple measuring devices. Do such conditions exist in Acton? YES, within range of any school expect to find little deserts, lakes, valleys, jungles and mountains!

For example:

LITTLE DESERTS - Well used paths, bare ground, gravel driveways, and parking lots represent deserts on a small scale. Many extremes of climate exist here and their effects on plant and animal life can be seen.

GRASSY JUNGLES - The school lawn or a nearby field may possess microclimates which are often similar to the jungles of the tropics. They may have temperatures of 100°F, a relative humidity of 90%, and no wind velocity.

VALLEYS & MOUNTAINS - These can be ant hills, ditches or gullies, embankments or large stones and boulders. The slope of any hill will affect the angle at which the sun's rays strike it, thereby creating interesting temperature variations.

LAKES - Puddles, and the water found in ditches after a rainstorm, modify the climate in their immediate vicinity just as lakes do.

UNDER TREES - The crown of a tree cuts off the incoming radiation from the sun during the day and radiation from the ground at

(continued)

(continued) Microclimates (Under Trees)

night. The tree also influences the wind velocity and the amount of precipitation. A light rain may never reach the ground under a tree or the water may continue to drip from the branches after a heavy rain has stopped.

The list could go on, both for outdoors and in. What might the difference in relative humidity be between your basement and the bathroom after a shower? What about the difference in temperature between the basement and the attic?

Microclimate (mc) pages involve much more activity and involvement than the demonstration experiments and as such form the experimental core of the unit.

WEATHER INSTRUMENTS (i)

All of the measuring tools needed for this weather study can be built easily using simple materials and construction techniques. The pages marked (i) include: an aneroid barometer, a liquid barometer, a wet and dry bulb hygrometer, a sling psychrometer (sounds formidible!), wind direction pencil and feather indicators, a wind speed flap device, a cup anemometer and a liquid thermometer. I have used all of them in the past with children and can testify to their utility and simplicity. I must point out however that there are many possible models for these instruments and much can be learned by having the kids try to construct their own. For example, when you begin to deal with the wind section tell the class that they will need to measure the speed and direction of the wind form some experiments. Present the challange to design/construct very simple tools to accomplish this task.

The experience allows the student to wrestle with such classic problems as uniformity, calibration, and simplicity when designing measuring instruments. It also helps one better comprehend the subject involved---constructing a good barometer forces the designer to understand air pressure and its effects. Humidity can be measured with cobalt chloride paper, a hygrometer and a

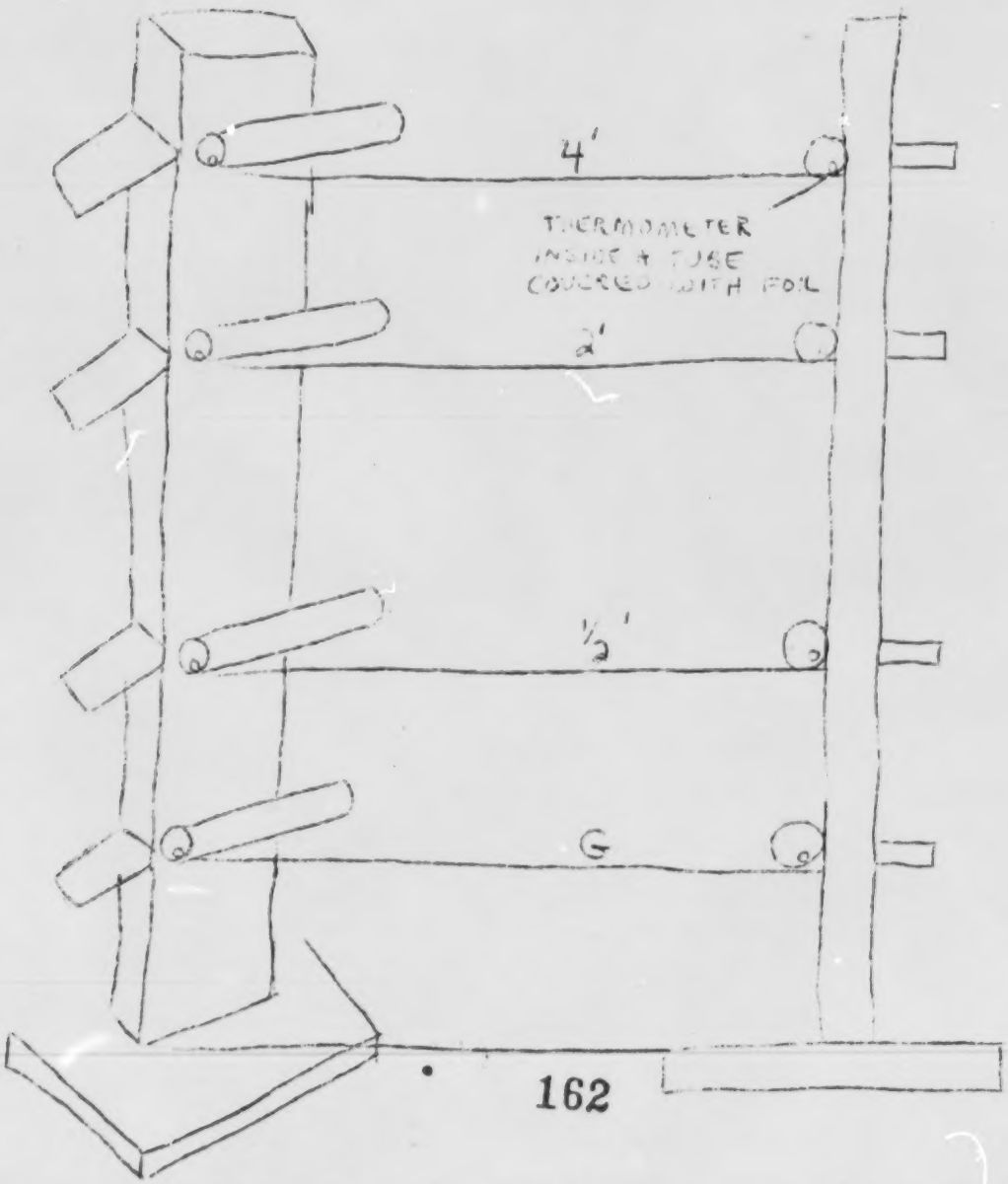
(continued)

(continued) Weather Instruments

sling psychrometer. Might there be an alternative to these instrument?

If you do not select this approach use the devices suggested, as long as the children understand how and why they work. Much of the work in microweather hinges on this comprehension.

MICRO WEATHER STAND



CLASSROOM TEMPERATURES

Background and Concepts

This is a simple and straight forward activity but one which involves some of the variables we will employ in many of the microweather experiments: measuring locations and heights, graphing the data, inferring and predicting from the results.

Each child should have a thermometer and should be reasonably skilled in its use. Discuss conditions that can alter a correct temperature and review the best procedures for reading the thermometer and recording the results. Break into 5-7 groups and ask each group to select eight locations to test, two of which should involve the variable of height, ie. above and below doorway, ceiling and floor, near the windows, etc. The group should take at least two readings for an object or location and allow a minute exposure time per object. (Ask the class to consider why these variables are important.) Before setting off to record, however, they should list the objects in estimate order of temperature, from warm to cool During the colloquium it will be fun to compare these predictions with the data chart.

Skills

- Measuring - temperatures and recording data
- Controlling variables - by considering two readings per location and setting a standard length for exposure time

Materials

1 - thermometer per child

recording sheets

Procedure

(1) Ask each to list his/her objects/locations and estimate the order of temperature. Some suggested places are: in the soil of a potted plant, in an aquarium, in their own hands, in a desk, on top of a desk, under a lighted lamp, near a

(continued)

(continued) Classroom Temperatures-Procedure

radiator, near the floor, near the ceiling, in the sunlight, on a chalk ledge, against the glass of a window, etc.

(2) Allow the groups to begin collecting data keeping in mind the qualifications and considerations mentioned in the background section.

(3) Have data recorded on a chart like the one outlined here:

	Location	Temperature C° or F°
# (1)		
# (8)		

(4) Allow each group to record the temperature from warmest---coolest before colloquium.

Colloquium

Was your hand warmer than you thought it would be?

Were you surprised by what turned out to be the coolest object in the room?

Was there any trouble in getting accurate readings? Is it warmer near the floor, or near the ceiling?

What things had about the same temperature? Would the results be the same if we did this experiment at night?

OUTDOOR TEMPERATURES

Background and Concepts

This activity almost exactly parallels the preceeding indoor experience. The same groups should operate, each child should have a thermometer, eight locations should be selected, thermal levels predicted and recorded, two of the locations should involve height, care should be taken with exposure time, etc. The difference of course is that we are now operating outside and subject to more factors and influences than the stable classroom usually holds. Some locations will be in the shade, perhaps others in the hot sun---an hour later and the conditions could be reversed. What about the height at which the temperature is recorded? The results at ground level above an asphalt parking lot could differ from a reading a yard above.

These two variables, time and height, are crucial in micro-weather and will be dealt with during the lengthy, day long, experiment that is a follow up to this inital activity. Here we will just look at locations and discuss the rough temperature differences among them.

Skills

- Measuring - temperatures and recording data
- Controlling variables - by using a standard procedure when taking readings
- Interpreting - differences in data
- Predicting variables - still to be considered

Materials

thermometers for all

recording sheets

Procedure

(1) Ask each group to list eight varied outdoor locations in order of estimated temperature--warm to cool. Some possible locations are: asphalt, a low cut lawn, high meadow grass, sand pit, concrete sidewalk, bottom of tree trunk, tree trunk at eye level, ground near the school, roof of school, forest,

(continued)

(continued) Outdoor Temperatures - Procedure

puddle, small pond.

(2) Allow experimenters about one half hour to complete their work and record their data on a sheet such as the one below:

	Location	Temperature C° or F°
# 1		
#8		

(3) Before the colloquium, have each group compare its data with the warm---cool prediction sheet.

Colloquium

What was the warmest spot? The coolest?

Were you surprised by the results? Was the temperature at the bottom of the tree trunk lower than at high level?

What are the factors we didn't consider that could change the results if we did them again? Sunlight or shade, time of day, height above ground---might these be important? (Mention that they will be able to explore these other factors in the near future).

HEIGHT and TIME VARIABLES (with TEMPERATURE)

Background and Concepts

This activity, or one like it, should follow hard upon the inital outdoor temperature experiment. It presupposes that you have been working with small groups, six or seven groups of four each for example, and that they have evolved a reasonable and equitable plan for sharing the responsibilities of data collection and recording. It requires that each group take temperature recordings at four height levels for eight spots, once every hour between 9 A.M. and 2 P.M. More height levels can be included if additional thermometers are available; the suggested areas included may be expanded but I think they provide an adequate transect of a school environment; the sun/shade consideration can be eliminated by constructing thermometer stands as described below. One or two members of each team can take the readings one hour and rotate with the others for the next. Before starting the "field" work brefly allow the groups to discuss their predictions.

Skills

- Controlling variables - location temperatures checked over time at various heights
- Predicting the outcome of the readings
- Recording and Measuring the information

Material

- adequate thermometers per group
- data sheets
- thermometer stands - one per group

Procedure

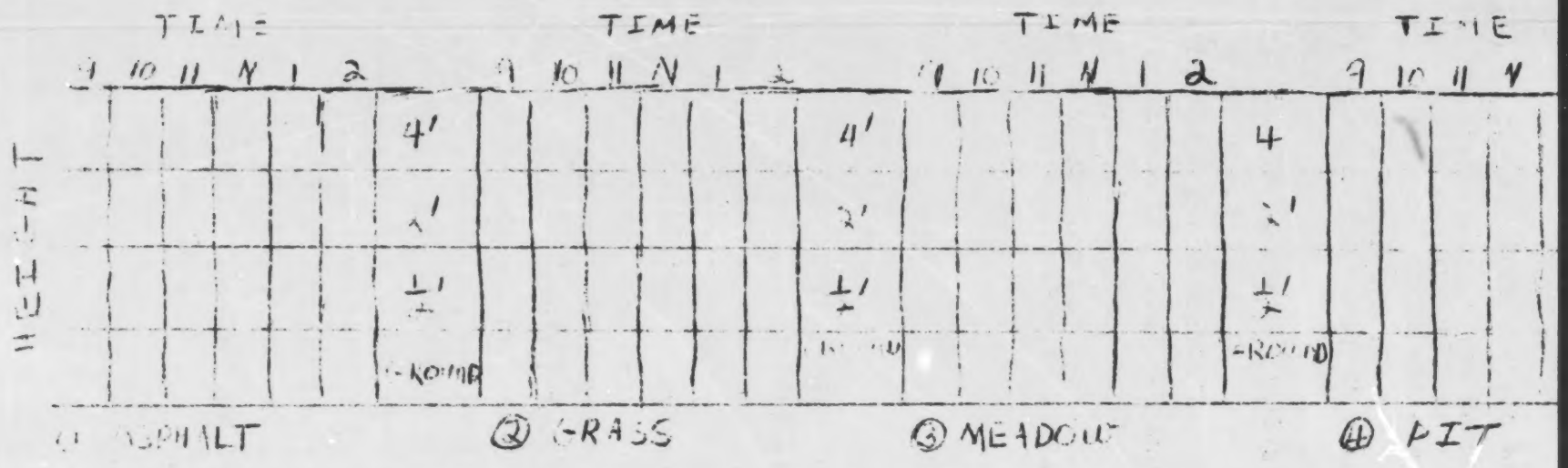
(1) Early in the morning, distribute one set of data sheets to each group and outline the procedure described above.

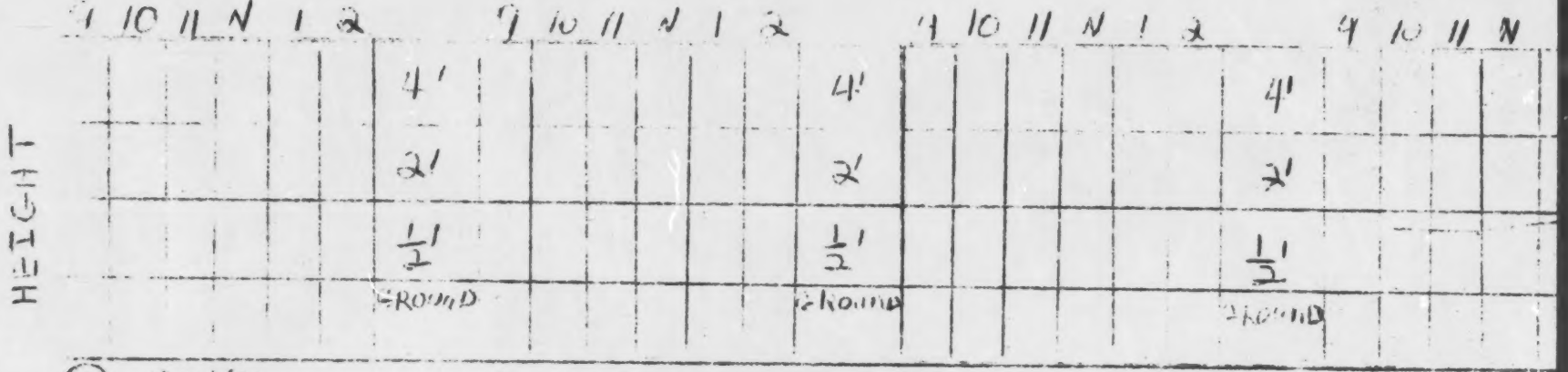
(2) Be sure the recorders are able to leave the class at five minutes before the hour so they can reach all eight stations before ten minutes after the hour.

(3) If the stations are too widely spaced, divide the

(continued)

HEIGHT AND TIME TEMPERATURE DIFFERENCES





(continued) Height and Time Variables (with TEMPERATURE)

Procedure

responsibilities and have each team be in charge of a few statinns rather than all eight. The data can then be transfered to a large class chart for all to observe.

Colloquium

Did the air temperatures above each surface vary according to height?

Where did it change the most? The least?

Why do you think?

What time of day produced the warmest temperatures? The coolest?

What stations temperatures changed the most over the course of the day? The least?

At what height are the temperatures the warmest?

Where do you think is the best place to take an average temperature for a station?....on the ground, at one foot, three feet?

The Highs and Lows of U.S. Temperature

Although 48 states of the continental U.S. lie in the North Temperate Zone and have a mild average temperature range of 40° to 70°F., they also have highs and lows almost as extreme as any in the world. In winter, each of these states has at one time or another experienced below-zero temperatures; in summer each has sweltered in 100° heat or higher. Indeed, much of the country is hotter in summer than most equatorial regions ever get. On the other hand, in some parts of the northern U.S., there are year-round killing frosts. The maps on this page, prepared by Dr. David Ludlum, show extremes of heat and cold, with dots to indicate where the readings were taken. Figures for Hawaii and Alaska are given in the captions accompanying the maps. Throughout the U.S., the greatest temperature extremes occur in inland regions, far from the oceans and their moderating effect on temperature.

U.S. RECORD TEMPERATURES

EXTREMES OF BITTER COLD . . .

U.S. cold-weather statistics contain a number of surprises. In the mountains of California, the record cold is −45° only three degrees above Maine's low of −48°. Florida has had only one below-zero reading in modern times. Both the extreme and mildest records for cold are in two states not shown: Alaska, with −78° and Hawaii, with a moderate 14°

. . . AND BLAZING HEAT

The record high-temperature reading in the U.S., 134°, is held by Death Valley, California. North Dakota, which has one of the coldest records (−60°), also owns one of the hottest (121°). Other extremes are Idaho (−60°, 118°), Montana (−70°, 117°) and Wyoming (−66°, 114°). Alaska and Hawaii have experienced identical extremes of heat: 100°

TEMPERATURE

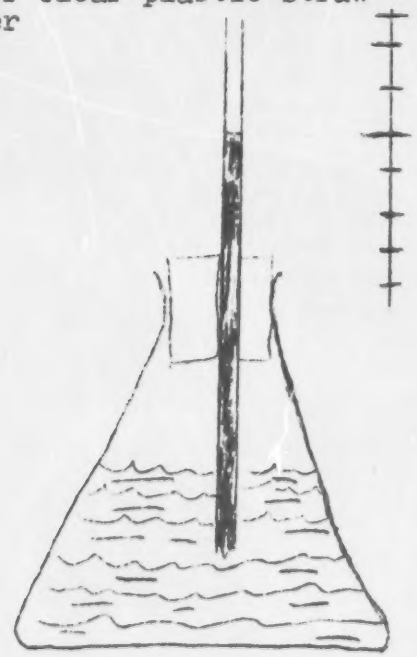
Liquid Thermometer

Background

I suggest commercial thermometers for most of the detailed experiments in this unit but it seems proper to include instructions for building one. This is a simple liquid themometer and constructing one should make clear the importance of standards and uniformity when creating a temperature scale---this process is called calibration. For an unique extension try building Galileo's air themometer---the first thermal measuring device ever constructed.

Materials

flask or bottle
one hole cork to fit the opening
long glass or clear plastic straw
dye and water



Procedure

(1) thrust the straw into the stopper
(2) fill the bottle 2/3 with colored water
(3) place the stopper on the bottle
(4) calibrate by using a regular thermometer
(5) use a cardboard background to lable temperature levels---

MICROWEATHER and HUMIDITY

Concepts & Background

The second factor we are going to consider in our study of microweather is moisture. One aspect of this can concern precipitation or the amount of moisture that actually reaches a microclimate. I have not included information about rain gauges and the like because many ideas are easily available in this area. If you do a detailed study of one or more microclimate stations, you will probably want to include a simple instrument or gauge to measure rainfall---an obvious but important consideration.

Here we will focus on how moisture returns to the atmosphere after it has fallen (evaporation), and how we can measure the water vapor content (humidity) of the air. You can use the stations suggested in the temperature section or add some such as: above and below bushes, on the sides of small hills, near a building, etc. In any event, the chief variables explored will be the humidity differences in various locations near school, and height factors. You should use the psychrometer for this experiment because it will allow for the fastest readings. Be sure to discuss the questions concerning the hygrometer and psychrometer before this experiment.

Skills

- Measuring - relative humidity using an exact instrument
- Controlling the variables - of height and location
- Predicting - possible results
- Recording information

Materials

one or two psychrometers per group, data sheets

Procedure

(1) Allow the class to predict which stations will record the highest relative humidity. Consider the issue of height,

(continued)

(continued) Microweather and Humidity(procedure)

will the same humidity be present at all levels?

(2) Produce a data sheet that includes height levels and stations and allow the groups to gather data

STATIONS

RELATIVE HUMIDITY CHART	Height	Grass	Asphalt	Pond	Forest	Etc.
	4'					
	2'					
	½'					
	Ground					

(3) Tell the children to notice the temperatures quickly after twirling since they can change very fast. All should have a copy of the R.H.% chart so they record the percentage without wasting time.

Colloquium

What surface had the highest R.H.? Did this surprise you? What surface had the lowest? Why do you think? Why is the relative humidity so high around plants? What would the R.H. be like in a jungle?...a desert? At what height was the R.H. the greatest? Why? Did it change as you measured higher? Why?

CLOUD - in a bottle

In the model rain experiement we produce a steam cloud and through contact with a cold tray cause condensation and water droplets to form. Another important factor, however, in cloud formation is air pressure. A decrease in air pressure can cool air enough to cause condensation of some of its water vapor. Prior work with "fluid dynamics" will make this procedure more understandable because the relatinnship between pressure change and temperature is a crucial one. If these experiences are absent be careful not to rush conclusions for which the children may observe no evidence.

The tiny drops condense in this experiment because the air in the jar cools when the rubber is pulled up. This is because the air in the jar then expands greatly. Since the same mass of air now takes up more space or volume, its pressure is less. Reducing the pressure causes the temperature of the air in the jar to fall---the air becomes cooler. The droplets evaporate quickly as the rubber is let go or pushed down. This is because as volume decreases the pressure increases and the temperature will rise and cause the droplets to evaporate. You can actually see this happen in our cloud chamber because the smoke from the match provides particles for the moisture to condense on.

Skills

- Observing - cloud formation through a model system
- Interpreting - large weather conditions in terms of the model
- Formulating hypotheses - about the nature of cloud formulation and air particle interaction

Materials

empty wide-mouth jar, large rubber balloon, wooden match, desk lamp (and dark room)

Procedure

(1) Pour a half-cup of water into the clean, empty wide mouth gallon jar.

(2) Cut a rubber diaphragm from the balloon

(3) Light a kitchen match, blow it out, then plunge it

(continued)

(continued) Cloud - in a bottle (Procedure

inside the jar and continue to hold it there while some of its smoke collects in the jar.

(4) Quickly cover the jar with the rubber and fasten it securely with rubber bands.

(5) In about ten seconds press down hard on the center of the diaphragm, hold it for a few seconds, then grasp its center and pull up hard.

(6) Repeat several times under the light of the lamp in a darkened room.

Colloquium

What happened to the pressure and temperature inside the jar when you pulled up? Why? What causes the tiny drops to condense? What caused them to evaporate just as quickly? Can warm air hold more moisture than cold air? (Why - Why not?) Why can you see your breath on a cold day?

Extensions

Water evaporates more quickly into warm air than into cold air, and warm air can hold more water vapor than cold air. Air at 80° F. can hold about six times as much water vapor as air at 32°F.

Ask the kids if it is possible to make a cloud in our chamber without the particles for the moisture to condense on. Discuss their answers and try it. A cloud can be made without smoke, but it will not be as dense. Thus, pollution, smoke, exhaust and airborne dust help in cloud formation because they provide a medium for vapor to condense. Another extension might be the cause of considerable cloud formation on the windward side of mountains. Have the class try to diagram or explain what happens to cause this. What weather might we expect if cold air pushes warmer air up out of the way? Does our experiment inform us about fog? How can fog be formed without the air being lifted? (Home challange) Given an ice tray and a hot plate can you make a fog?

MODEL RAIN

Concepts and Focus

The forces which combine to produce any form of precipitation are numerous and complicated. However this classic table top experiment clearly isolates the significant variables in the rain cycle in a demonstrable fashion. (If the class has done prior work with "Fluid Dynamics" the key concepts of evaporation and condensation can be dealt with quickly.) The crucial concepts involve the changing of water from a gas to a liquid through the process of evaporation and condensation.

While the hot plate is warming up you might place a few drops of water on both your hand and the hot plate. Discuss the fact that water changes states from a liquid to a gas through the heat energy provided by the surfaces receiving the drops...the speed of transfer---slow for your hand, faster on the plate---is determined by the amount of heat involved. This process is called vaporization. Drop some more water on the hot plate and quickly hold a test tube above the rising steam. The trapped vapor will change into the liquid state and should be visible in the tube. The cooler the test tube the faster the transfer. This process is known of as condensation. (Depending on the science experience and background of the class some of you might want to discuss physical change from a molecular viewpoint. When doing this model rain experiment with my class last year we discussed whether this process could take place in a vacuum since we had worked with pressure/volume/density issues in "Fluid Dynamics". Does it rain on the moon? On Mars? The best medium for this vaporization/condensation exchange is the reasonably dense atmosphere of the earth. If water were placed on the arid moon it would quickly evaporate, but would not form a cloud because the moon has no atmosphere and little gravity. These are some possible extensions to explore during colloquium.)

(continued)

(continued) Model Rain (Precipitation)

Precipitation

Rain occurs when water evaporates from the surface of the earth and rises high into the air where it is cooled. Here it condenses into little droplets that float in the air as clouds. As the droplets come together to form larger drops they become heavier than the air and fall to the ground as rain. The hot plate/ kettle, represents the surface of the earth and the ice pan corresponds to the high cool air. The suggested terranium will obviously represent anouther part of the earth where the rain will actually fall.

Skills

- Observing - the interaction of the model elements in the experiment
- Inferring - information about states of matter and the thermal forces needed to cause them
- Interpreting - the experimental sequence in terms of the rain cycle

Materials

Hot plate, kettle, 9" x 12" (or so) baking pan, terranium (or any surface to represent the earth), ice cubes

Procedure

(1) Fill the kettle with water and allow it to come to a full boil on the hot plate.

(2) Hold or suspend the baking pan (filled with ice and water) over the rising steam and allow the vapor to condense on the pan.

(3) Position the terramium to catch the water droplets.

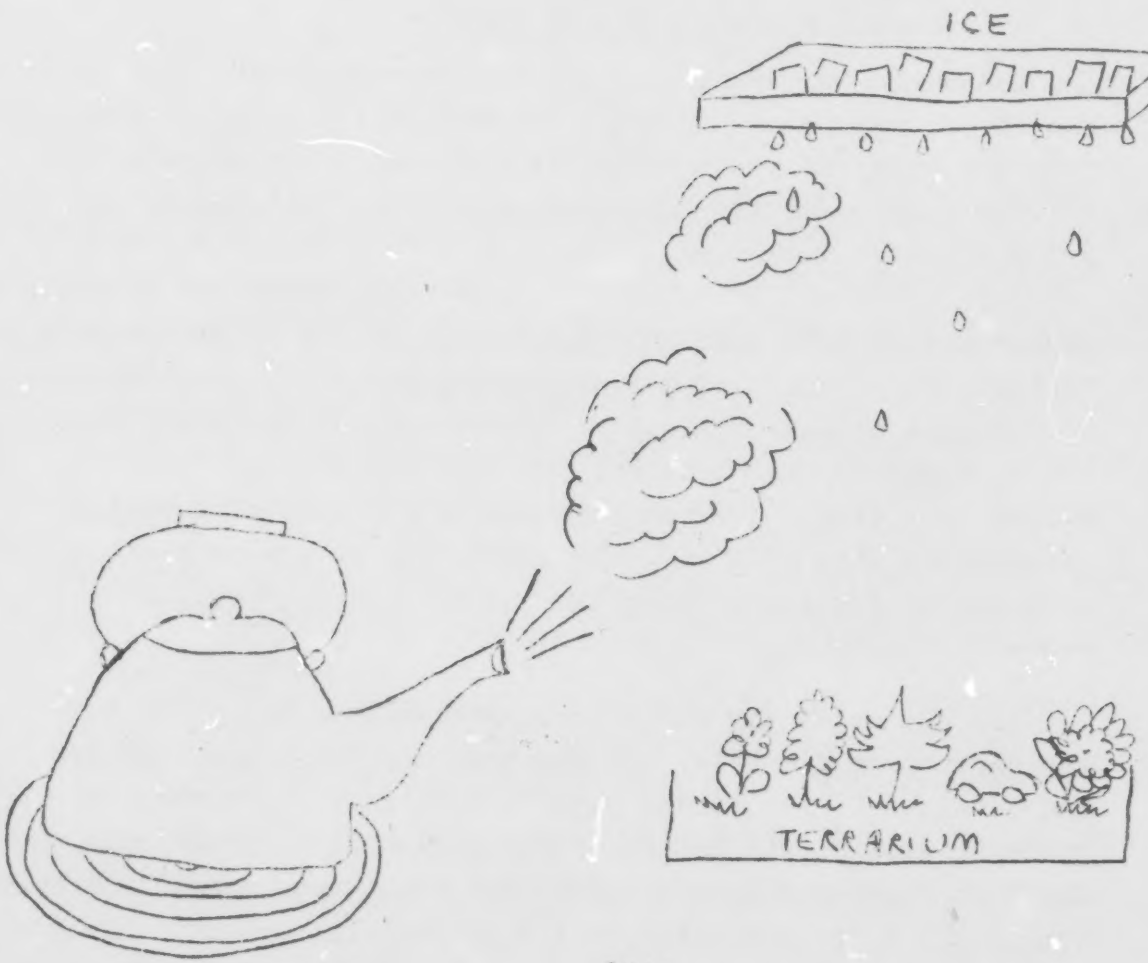
(4) A possible extension might be to produce snow, actually frost, on the bottom of the pan by replacing the ice and water with dry ice or a mixture of salt and ice. Snow is formed when water vapor is changed directly into solid particles at temperatures below freezing. (This is called sublimation). Patience is required but you can produce frost and have it fall on your terranium if dry ice is used in the pan.

(continued)

(continued) Model Rain (Evaulation)

Evaulation

What do the hot plate, kettle steam and baking tray represent? What happened? Why? This process has often been referred to as the "water cycle" -- do you think this is a good expression for what you observed? How was this experiment like real rain and snow? How was this model unlike real weather rain?



COBALT CHLORIDE - HUMIDITY INDICATOR

Concepts and Background

The "humidity indicator" presented here is not the most technically accurate way to measure water vapor content in the air. However, it has a general utility as a weather indicator, and the process of making them generates simple scientific phenomena and a pleasurable aesthetic. Every child can have one as part of his/her weather station and should be able to make several for home if he/she desires.

Cobalt Chloride is a redish crystal with a chemical formula of $CoCl_2$ $6H_2O$.. This obviously indicates that in an unaltered state it contains quite a bit of water.

The children should know from prior experiments that water can be removed from a substance through the process of evaporation. From our study of the water cycle and model rain we know that the heat energy of the sun evaporates water from the earth and generates the eventual formation of clouds. Put a few crystals of cobalt chloride in a test tube, heat over an alcohol burner and it will turn from liquid red to liquid blue---from $CoCl_2 6H_2O$---$CoCl_2$. Add a few drops of H_2O and it will quickly revert back to the original red color because the water restores to the chemical what was lost during evaporation. If we dip a cloth or filter paper in a saturated solution of cobalt chloride we will have tangible indicators of the presence of moisture in the air keeping in mind the simple formula: red--wet, blue--dry.

Dry and moist air can be simulated with a hot plate and the vapor from a kettle. If you take the first sheet of wet red cobalt chloride filter paper and hold it above the hot plate it will slowly but beautifully turn blue. Take this dry blue paper and hold it above the rising steam from a kettle (or simply drop some water on it) and it will dramatically turn red. Discuss the phenomena informally and prccede to the mass production phase of the exercise.

(continued)

(continued) Cobalt Chloride-Humidity Indicator

Skills

- Observing - various color changes through the addition and/or evaporation of water
- Inferring - about the chemical changes
- Predicting - color changes based on the experimental conditions altered
- Measuring - moisture content in the air

Materials

(For presentation so far)

. Cobalt Chloride crystals
. test tube, holder, alcohol burner
. medicine dropper
. filter paper
. hot plate & kettle

(For production)

. one or two plastic dish basins
. fifty or so sheets of filter paper(6" diameter)
. ½c $CoCl_2\ 6H_2O$
. long string & paper clips

Procedure

(1) As outlined above mix the $CoCl_2 6H_2O$ crystals with a gallon or more of water in the dishpan

(2) String the cord rather tautly across the room once or twice at about a 7' level.

(3) Provide each child with a piece of filter paper and allow them to dunk the paper in the solution.

(4) Have everyone paper clip the indicator to the line and repeat the process if desired.

Colloquium Note

While having the colloquium the kids will notice the slow change of the fifty or so paper disks from red to blue (most classrooms are rather dry). Also, their hands which were once red from touching the solution, are now light blue! Start by asking why? (Remember our hands act like hot plates relative to the temperature of the liquid drop of red $CoCl_2 6H_2O$.) Why

(continued)

(continued) Cobalt Chloride-Humidity Indicator -Colloquium

are the disks slowly changing colors? Why did the dry blue disk turn red (or pink) when exposed to steam or water? If you breathe on your blue dyed hands what will happen? Why? What did the air above the kettle stand for in terms of atmospheric conditions?....the air above the hot plate? What would be the best place to hang a moisture indicator at home? Should it be exposed to rain?...Near a radiator?

This experiment requires at least one hour or more to complete. The next day you might mount the indicators by outlining them with cardboard strips. This will protect them from tears and allows them to be attached to a string. Save several for the class weather station and later experiments. Encourage each child to take one home.

MOISTURE

Wet & Dry Bulb Hygrometer

Background

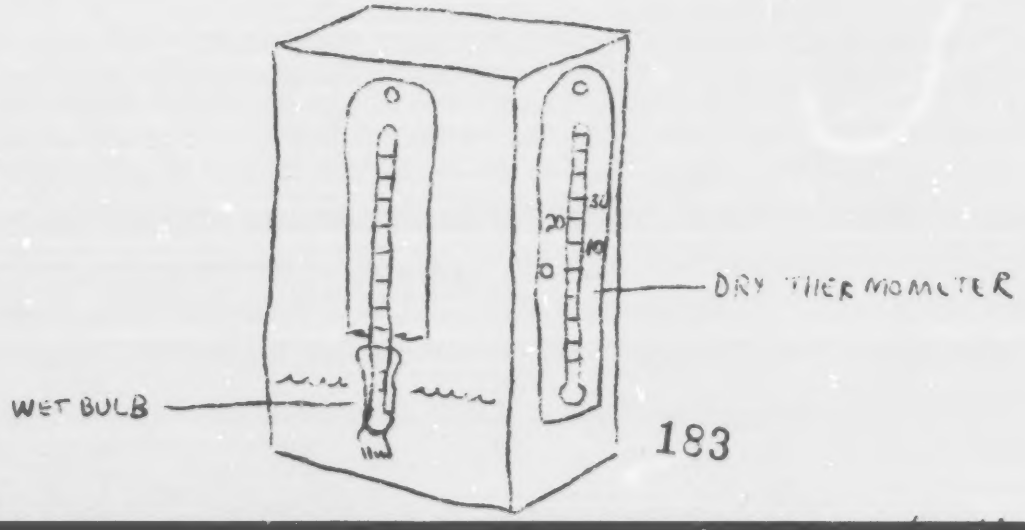
The relative humidity is the per cent of moisture in the air compared to the maximum amount of moisture the air can hold at a given temperature. The higher the temperature, the greater amount of moisture the air can hold.

(The cobalt chloride paper is a humidity indicator but is not included here.)

When we fan or twirl the wet bulb thermometers in the experiments below it should be clear that evaporation is a cooling process because it releases heat. Swimmers feel cool as water evaporates from their skins. Clothes on a line become much cooler as water evaporates from them. Our own perspiration evaporates to cool us when we exercise. Evaporation from lungs, from the tongues of panting animals, evaporation from the leaves of trees, the surface of lakes, streams, soil and the sea, from rain---all these are cooling processes.

Materials

two indentical thermometers
piece of cotton shoestring
one quant cardboard milk carton



(continued) Wet and Dry Bulb Hygrometer

Precedure

(1) Attach the thermometer to the sides of the milk carton and secure with rubber bands.

(2) Slip one end of the shoelace over the bulb of one of the thermometers and let the other end rest in a cup of water inside the milk carton.

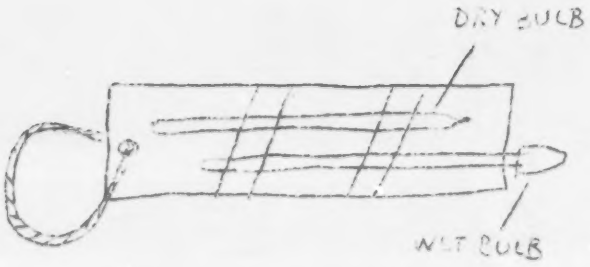
(3) Fan the wet shoelace and notice the diffeeence in temperature between the two thermometers. What happens as water evaporates from the string?

(4) Note the difference between the two readings and locate this number on the scale provided. Next find the dry bulb reading on the side of the chart--at the intersection of these two columns you will find the relative humidity expressed as a °/o.

SLING PSYCHROMETER

Materals

narrow board with small hole at top
two identical thermometers
strong cord
shoestring for one thermometer



Procedure

(1) Secure the two thermometers to the board but allow one to extend over the end so it can hold the wed gauze.

(2) Tie the cord through the hole in a loop.

(3) Operate by wetting the shoestring and whirlling the system overhead for a minute.

(4) Note the difference between the two readings and determine the relative humidity by using the chart.

Colloquium

What did fanning or twirling the wet bulb thermometer do to the moisture on the string? What is this process called? (Evaporation requires heat but what does it do to the surface that provided the heat?) If the difference between the two thermometers is low, is the air moist or dry? If the difference

(continued)

30 A

CENT OF RELATIVE HUMIDITY—F°

p. of Bulb	Difference in degrees between Dry Bulb and Wet Bulb																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
98	96	93	89	86	82	79	76	72	69	66	63	60	57	54	52	49	46	44	41
96	96	93	89	85	82	78	75	72	68	65	62	59	57	54	51	48	45	43	40
94	96	93	89	85	81	78	75	71	68	65	62	59	56	53	50	47	44	42	39
92	96	92	88	85	81	78	74	71	67	64	61	58	55	52	49	46	43	40	38
90	96	92	88	84	81	77	74	70	67	63	60	57	54	51	48	45	42	39	36
88	96	92	88	84	80	77	73	69	66	63	59	56	53	50	47	44	41	38	35
86	96	92	88	84	80	76	72	69	65	62	58	55	52	49	45	42	39	36	33
84	96	92	87	83	79	76	72	68	64	61	57	54	51	47	44	41	38	35	32
82	96	91	87	83	79	75	71	67	64	60	56	53	49	46	43	40	36	33	30
80	96	91	87	83	79	74	70	66	63	59	55	52	48	45	41	38	35	31	28
78	95	91	86	82	78	74	70	66	62	58	54	50	47	43	40	36	33	30	26
76	95	91	86	82	78	73	69	65	61	57	53	49	45	42	38	34	31	28	24
74	95	90	86	81	77	72	68	64	60	56	52	48	44	40	36	33	29	26	22
72	95	90	85	80	76	71	67	63	58	54	50	46	42	38	34	31	27	23	20
70	95	90	85	80	75	71	66	62	57	53	49	44	40	36	32	28	24	21	17
68	95	90	84	79	75	70	65	60	56	51	47	43	38	34	30	26	22	18	15
66	95	89	84	78	74	69	64	59	54	50	45	41	36	32	28	23	20	16	12
64	94	89	83	78	73	68	63	58	53	48	43	39	34	30	25	21	17	13	9
62	94	88	83	77	72	67	61	56	51	46	41	37	32	27	23	18	14	10	5
60	94	88	82	77	71	65	60	55	50	44	39	34	29	25	20	15	11	6	2
58	94	88	82	76	70	64	59	53	48	42	37	31	26	22	17	12	7	2	
56	94	87	81	75	69	63	57	51	46	40	35	29	24	19	13	8	3		
54	93	87	80	74	68	61	55	49	43	38	32	26	21	15	10	5			
52	93	86	79	73	66	60	54	47	41	35	29	23	17	12	6				
50	93	86	79	72	65	59	52	45	38	32	26	20	14	8	2				
48	92	85	77	70	63	56	49	42	36	29	22	16	10	4					
46	92	84	77	69	62	54	47	40	33	26	19	12	6						
44	92	84	75	68	60	52	45	37	29	22	15	8							
42	91	83	74	66	58	50	42	34	26	18									
40	91	82	73	65	56	47	39	30	26										
38	91	82	72	64	56	46	38												
36	90	80	71	62	54	46													
34	89	79	69	62	54														
32	89	78	68	61	48														
30	88	76	66	56	47														
28	87	75	65	53	43														
26	86	73	63	50	38														
24	85	71	60	47															
23	85	70	58																
22	85	69																	
21	85																		

(continued) Sling Psychrometer

between the two thermometers is high, why is the humidity low? Would you expect the humidity in your home during winter to be high or low? Why? Why should there be some moisture in the air for comfort? Why is it that if the temperature outside in the summer drops to 65° you are very comfortable, but if the temperature in your home is 65° in winter you are cold? If the relative humidity is 100% can evaporation take place?

AIR

I. CONVECTION CURRENTS

I will suggest here several variations on the classic air and water convection current experiments. The materials and procedure differ in each example but all illustrate the same basic principles. Accordingly, the backgroud information provided, and the suggested colloquium questions, can be easily adapted for the experiments you select.

In a thermal sense,/
/winds are caused by the uneven heating and cooling of the earth. The air is heated by coming into contact with the warm earth. When air is warmed it expands and becomes lighter. As it rises it is replaced by colder air resulting in a circulating pattern of warm and cold fluids called convection. If the earth were not rotating, and if there were no complications resulting from the presence of continents, oceans, and pressure densities, a huge but simple convection circulation would probably result. Air would rise at the equator, sink at the poles, and move horizontally between these latitudes. The model presented deals only with this simple circulatory flow, and avoids the other complicating variables.

Convection currents cause local breezes as well as global circulation. In coastal regions a breeze commonly blows from the sea onto the land during the day (sea breeze), and from the land to the water at night (land breeze). During the day the air over coastal areas becomes warmer than the air above the ocean because land heats more quickly than water. Cooler air above the ocean moves inland to push upward the warmer lighter air over the land. At night the process is reversed when the land radiates its heat away quickly, whereas the temperature of the water varies little. As a result the cooler, heavier land air moves seaward to push up the lighter warmer nocturnal air. Also, mountain and valley breezes can be easily understood if we realize that mountains absorb heat faster during day light than nearby valley, and lose it faster during the night.

(continued)

(continued) Convection Currents-AIR

These basic convection principles apply to water and the various currents that flow through the world oceans and affect weather. Great Britan has a relatively moderate climate even though it is on the same latitude with Labrador because it is happily affected by the warm Gulf Stream. (The Gulf Stream is one of the world's largest ocean currents--10°F warmer than the surrounding ocean, a mile deep and 300 ft. wide in places. National Geographic "World" Magazine has an interesting article about ocean currents in its May, 1976 issue)

Skills

- predicting - the outcome of the various experiments
- inferring - hypotheses about larger systems from the models presented

Materials

(A)Experiment

aquarium tank
cardboard lid for the tank with two openings for plastic tubes or kerosene chimney lamps
candle
small dish of ice water or dry ice
matches
rope or paper for smoke trail

(B)Experiment

two glasses or jars of equal size
matches and rope or paper for smoke production
materials to chill one jar and heat the other

(C)Experiment

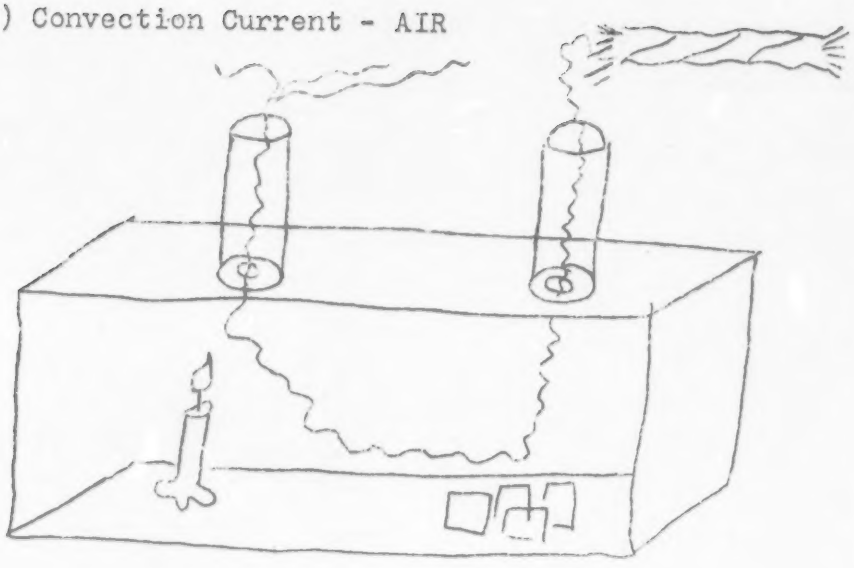
Aquarium tank
small jar fitted with a two hole stopper and two straws-one pushed down to the bottom of the jar the other projecting out from the cork.

(D)Experiment

same jars used in Ex. B.
red or blue dye
cold and hot water supply
3" x 5" card

(continued)

(continued) Convection Current - AIR



Procedure

(A) Experiment

(1) Put lighted candle and the ice tray in the bottom of the tank directly underneath the two tubes.

(2) Hold a smoking rope or paper over the tube with the ice tray.

(3) Notice the path of the smoke. It might be easier to follow the trail if a piece of black construction paper is held up behind the aquarium opposite the children.

(B) Experiment

(1) Chill the air inside one jar by leaving it in an ice water bath for about five minutes

(2) Heat up the air in the other jar with a hot plate or alcohol burner

(3) Turn the warm jar upside down, force smoke into it and

(4) quickly place on top of the cold jar. The heated smoke should not mix with the cold and will stay in the warm upper jar.

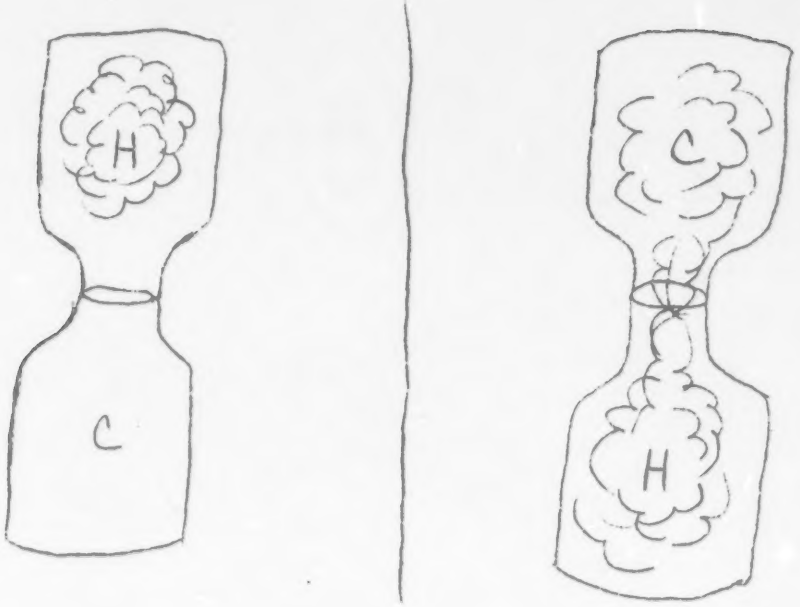
(5) Ask the children to predict what will happen if you turn the system upside down and have the warm smoke filled jar on the bottom.

Try it and see.

(continued)

(continued) Convection Currents - Air

Procedure



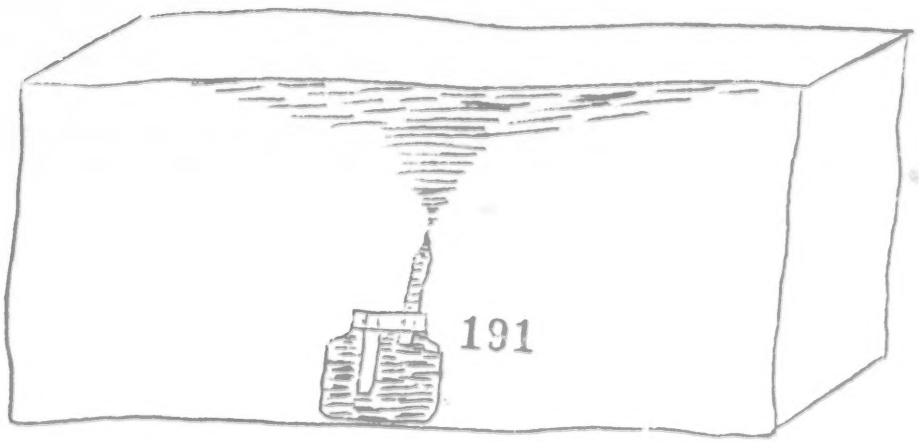
(C) Experiment

(1) fill the aquarium tank with cold water

(2) fill the small bottle with hot dyed water

(3) With minimal disturbance quickly lower the small jar into the tank.

(4) Observe the current of the warm water after the children have had an opportunity to predict the outcome.



Convection Currents-AIR

(D) Experiment

(1) Fill one jar with hot dyed water.

(2) Fill the other to the surface tension brim with very cold water and and cover with an index card or small plastic sheet.

(3) Cover the warm jar with a card, turn upsidedown, and place directly on top of the cold vessel.

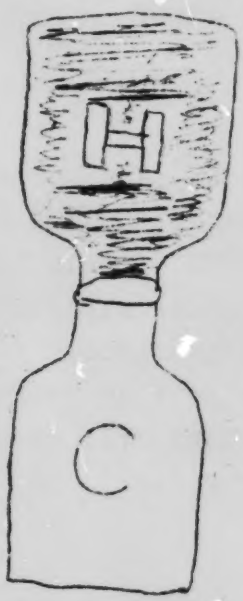
(4) When the children have discussed what might happen carefully withdraw the cards and observe what takes place .

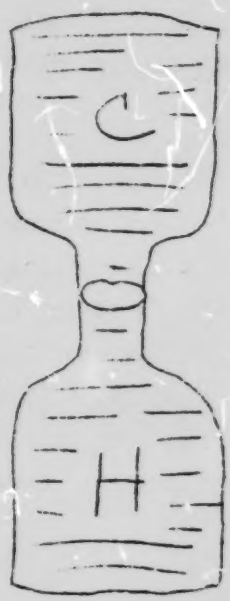
(5) As in Ex. B. discuss the outcome when we invert the system and have the warm dyed water on the bottom .

Evaluation

What happened during each experiment and the suggested variations? What did the various objects represent in each of the experiments with reference to convection currents and weather systems? Can we look at the air flow models in terms of simple global and local wind circulation? Do the water models inform us about ocean currents--eg the Gulf Stream? How are these models inadequate for demonstrating water and air currents---what factors and variables are missing?

(Extension) - Can we compare these models to hot water and air heating systems in our own houses?





Bottle Release -Extension- AIR

Background

It is said that Columbus during one of his exploratory journeys to America encountered a ravaging storm and feared for his life and that of his crew. Rather than have news of his latest discoveries be lost forever, he placed his log book and other valuables in a sealed waterproof barrel and threw it overboard. Fortunately, and to his surprise, Columbus survived the storm, but his valuable barrel could not be recovered. Beachcomers for later generations looked in vain for this prize in the hopes that some powerful ocean current carried it far from its original spot.

This storm affected me so when I was young that I searched often for this mystery barrel.

Actually the desperate Columbus was anticipating a "letter in a bottle" technique that scientists have used for years to learn how the ocean currents work. For example, a bottle dropped in the Gulf Stream off Florida could end up along the east coast of the United States, or as far away as many parts on Northern Europe. "World" magazine dropped 1000 bottles into the Gulf Stream during May, 1976 as part of an experiment and asked their readers to look for them.

Procedure

If the opportunity presents itself and you know of someone who will boat through the Gulf Stream, it might be fun to do the liquid equivilent of the balloon release. Simply have the kids write letters as they did with the earlier experiment and secure them within a well sealed, perhaps waxed, clear, bouyant bottle. If released carefully the bottles could hitch a ride on one of the ocean's rivers that will transport them, and your children's imaginations, very far.

WINDS - II. (A) Coriolis Force

Background

The simple thermal convection patterns demonstrated in the last set of experiments do not account for pressure differencials and the earth's rotation. Here we will look at the earth's spin and the wind deflection that results. Again our model is not a perfect replica for the real thing, but it can inform us to a significant degree about global wind systems.

Take a globe that can be removed from its stand and spin it west to east--which is the rotational direction of the earth. Now look at this spinning globe from above the North Pole and notice its direction of spin--counter clockwise. Without altering the direction of the spin, hold the globe above your head and view it from the South Pole. In what direction is it moving? Does the answer clockwise surprise you? It does for most of us because we tend to overlook the fact that motion is relative to the viewer. If you like, provide several globes for your class and allow the children to explore this phenomena. How can an unaltered rotating orb appear to turn in a counter-clockwise direction when viewed from above (Northern Hemisphere), and clockwise when viewed from below (Southern Hemisphere)? This seeming paradox can be examined in depth if desired, but it is included here as a starting point for viewing global wind circulation.

Most of us have a vague sense of the importance of the polar easterlies, prevailing westerlies, trade winds, horse latitudes and doldrums as they relate to weather, but perhaps little sense of why they act and are so named. Instead of all winds blowing (through simple convection)north and south on a stationary globe, the rotation of the earth deflects them into prevailing easterlies and westerlies. As the earth spins eastward all moving objects in the Northern Hemisphere tend to veer to the right, and in the Southern Hemisphere to the left. This Coriolis Force can be demonstrated easily with the

(continued) WINDS -II. (A) Coriolis Force

Background

turntable experiment described below.

(It should be noted that winds are named for the direction from which they are coming. An "east" wind comes from the east and is flowing toward the west.)

Skills

interpreting - deflection current systems in terms of a turntable model

observing - the unique properties of straight line motion on a moving surface

Materials

turntable

cardboard disk the size of a record

perhaps covered with a polar map of the Northern Hemisphere

two magic markers

ruler

Procedure

(1) Pinch a hole in the center of the cardboard and have it stand for the North Pole. The rim of the circle will stand for the equator.

(2) Spin the turntable in a counter clockwise direction the way it is viewed from above the North Pole

(3) Using a ruler as a guide, draw a straight line from the center of the disk to the edge while the record is turning. Note how the easterly rotating record causes the line to curve toward the right. Do this a couple of times and indicate the direction of the line with small arrows.

(4) Using a different color marker draw a line from the rim of the record to the center and note the direction of the deflection.

(5) The obvious extension is to reverse the direction of the turntable to the Southern Hemisphere perspective (clockwise) and repeat the experiments.

Colloquium

What does the turntable stand for in our model? The center? The rim?

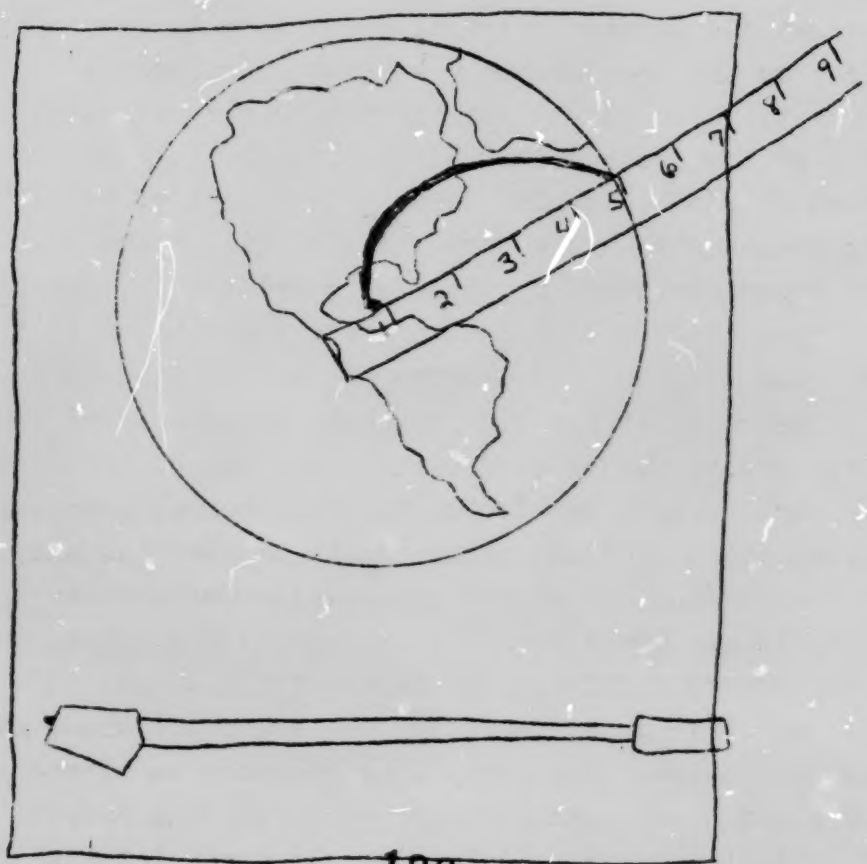
(continued)

(continued) Coriolis Force - Colloquium

With a counter-clockwise spin the deflection or curve of the line is always toward what direction? Why do you think? Why is the deflection always the reverse (left) with a clockwise spin? Wind coming from the North Pole will flow in what direction? Wind coming from the equator will flow in what general direction? Would this be true if the earth did not rotate?

In the Northern Hemisphere rivers, projectiles, ocean currents and hurricanes all veer to the right in a counter-clockwise direction. Would this be opposite on the Sourthern Hemisphere? Does our model make this clear? Can this "Coriolis Effect" determine how water empties from a bathtub!?!

Try it at home and see.



WIND - II. (B) Global Air Circulation

Background

Part A above demonstrated that one component of air flow is the deflection caused by the spin of the earth. This section will combine the Coriolis Effect and our knowledge of convection. It involves general global circulation and is an optional exercise. If your purpose is to look at the causes of wind and its application with reference to hemispheric circulation and prevailing air flow, then try it. It is important to note that this extension does not involve any demonstration or experimentation, but does include the introduction of much new vocabulary. If the kids find the terminology overwhelming consider skipping this part.

We know from our work to date that wind is really moving air and has vertical as well as horizontal components. The air over the equator has very little horizontal movement because the heat of the sun lifts it almost straight up. This belt of low pressured air is called the doldrums since sailors found little horizontal wind in this area of calm. This rising air branches out like a fountain (we will focus only on the N.H.) and forms northward upper-level currents. By the time this air has gone about 1/3 of the way from the equator to the North Pole it begins to cool and descend at the 30° Latitude. This creates another vertical air high pressure column called the "horse latitudes." (Ships caught in this becalmed area sailing to the New World were often forced to throw horses overboard to conserve needed food and water and to lighten the ship.) When the descending air of the horse latitudes reaches the earth it divides. One stream heads toward the equator, deflectes right (west) and forms the famous trade winds. (Columbus not only discovered new territory but found the trade winds that blew him there. For most of his journey he zipped along at 100 miles a day with a steady easterly wind, carefully avoiding the potentially fatal delays of the horse latitudes). The other air stream from the 30° horse latitude line moves poleward,

(continued)

(continued) Wind - II. (B) Global Air Circulation

deflects right and becomes the prevailing westerlies. The westerlies circle the earth in undulating currents between the 30th and 60th parallels and hence are the major air flow across the United States. Weather in the United States would be constantly fair and stable because of these winds were it not for polar invasions and complications caused by mountains. The last band of winds that make up the general circulation are the polar easterlies. The frigid air from the pole moves southward but is deflected by the Coriolis Force and moves from east to west. When the polar easterlies clash with the prevailing westerlies around 60°, both with different temperatures and humidities, it forms the constantly changing polar front. This convergence is very irregular and frequently developes huge bulges that extend southward into the middle latitudes. Most of New England's changeable weather originates along this episodic and capricious line.

Skills

Classifying - winds according to deflection forces and latitude

Predicting and inferring- from colloquium questions which extend the model

Materials

Outline maps for all/markers

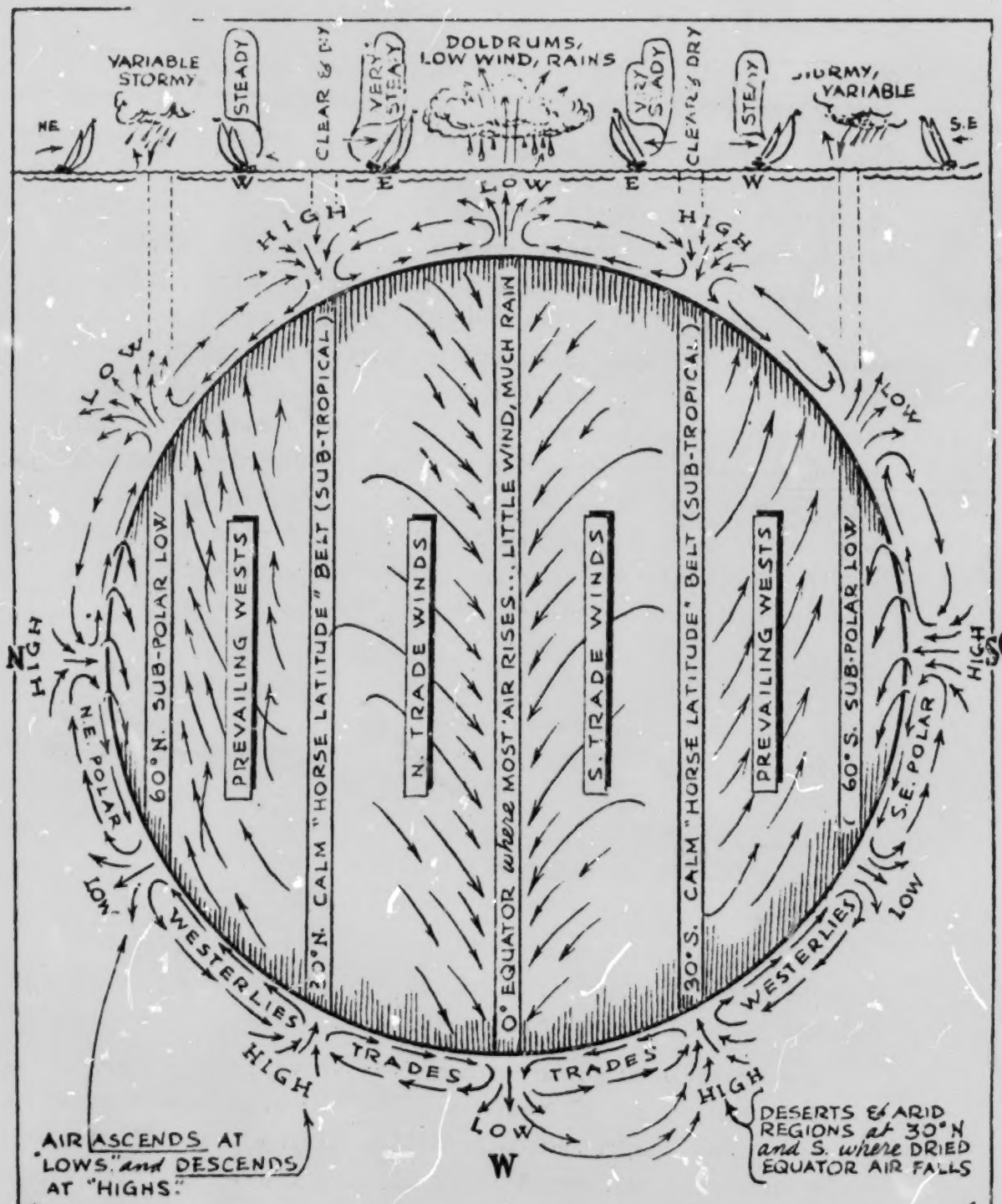
Procedure

Using world, northern hemisphere and United States outline maps as a starting point it should be easy to sketch out the general global circulation.

The brief background information above is similiar to that found in many texts on weather. You can simply present it to your class as background information having them illustrate their maps with the broad lines of wind flow. Or, more ambitiously, it might be fun to have your group try to generate what they feel the world wide circulation is like based on their knowledge of Coriolis Force and convection. Where on earth would hot convected air be most prevalent? Would this

(continued)

42A



An IDEALIZED CHART of PRESSURE and PREVAILING WIND distribution

BELTS OF PRESSURE

Heat is airlifted and passed along from the tropics to the poles by this system of wind cells. In the process some general patterns of weather evolve. Where air currents have a tendency to flow downward, as at the poles, high-pressure areas are fairly constant. Where air circulation is upward — for example at 60° latitude — a predictable band of low pressure occurs. Again, descending air at the junction of the mid latitude and tropic belts creates the zone of high pressure and light winds which for centuries has been colloquially known as the horse latitudes. Rising tropic air near the equator accounts for the low-pressure area called the doldrums. Here, because the movement of the air is generally vertical, the equatorial seas are calm, disturbed only occasionally by fitful winds that do not blow for long in any one direction.

(continued) Wind-II.(B) Global Air Circulation-
Procedure

spot produce horizontal air flow? Would it be a good place to sail a ship? What do you think might happen to cold polar air after it flows southward for awhile? Given this spirit of questioning (and a little factual information that you add throughout the discussion) it should be fascinating to observe the model for air flow the kids generate, and compare it to the accepted system already outlined----one which, by the way, took years of research by meteorologists. Don't force the issue by telescoping the wisdom of many generations into a sixty minute science lesson.

BALLOON RELEASE - Extension

Background

This is an increasingly popular activity in schools across the United States, however it is often done poorly. It involves releasing helium balloons (with self-addressed post cards attached) into the upper atmosphere in an attempt to measure large scale air flow in the upper atmosphere. It was first done in California taking advantage of the prevailing westerlies that blow across the United States. The elementary school involved received a 10% return on the cards----many cleared the Rockies and landed several states away. However if this activity is done on the east coast with a westerly wind, all will soon be lost over the Atlantic. The relatively low return that will result will prove the power of the prevailing westerlies that sweep across our country but the kids will surely be disappointed by the absence of response.

If you do this activity in Acton collect and prepare all the needed materials in advance and patiently await the proper wind conditions. By looking at maps and discussing the situation the class will certainly conclude that not just any old day will do--a NE, E or NW wind is needed to send the cards overland. When the great day arrives give yourself plenty of time to fill the balloons and release from an open field.

Materials

helium supply for 75-100 balloons
postcards and stamps
balloons
string and hole pinch

Procedure

(1) Fill out postcards with a message similiar to the following:

(continued)

(continued) Balloon Release - Extension

Procedure

Time found_____Place found_____

This card is part of a wind study. Please note when and where you found this card and mail back. If you would like to write me a letter telling how you found it, please do.

Thanks,

Signed: _____

(2) Cover the postcard with plastic wrap if you like.

(3) Obtain the helium from a compressed air supply place (try Airco in Acton).

(4) Pinch a small hole in the postcard and secure to the balloon with a short string. Reduce drag wherever possible--use small cards, light string, trim edges, etc.

(5) When using the helium do not fill the balloons to capacity. Why? As the balloon ascends it encounters lower pressure causing the balloon to expand and burst if it has no room to stretch.

(6) Plot recovery points on a map during the days following the release.

Extensions

When doing this activity last year with my class some kids worked on a balloon release which they hoped would reach the jet stream. (The jet streams are a topic you might want to consider when studying global air patterns.) To accomplish this they decided to attach several balloons to one card, each with a different amount of helium. They reasoned that if one or two balloons were filled to capacity with helium they would expand and blow up, but not before giving the card a quick ascent. The partially filled balloons would then fill out in

(continued)

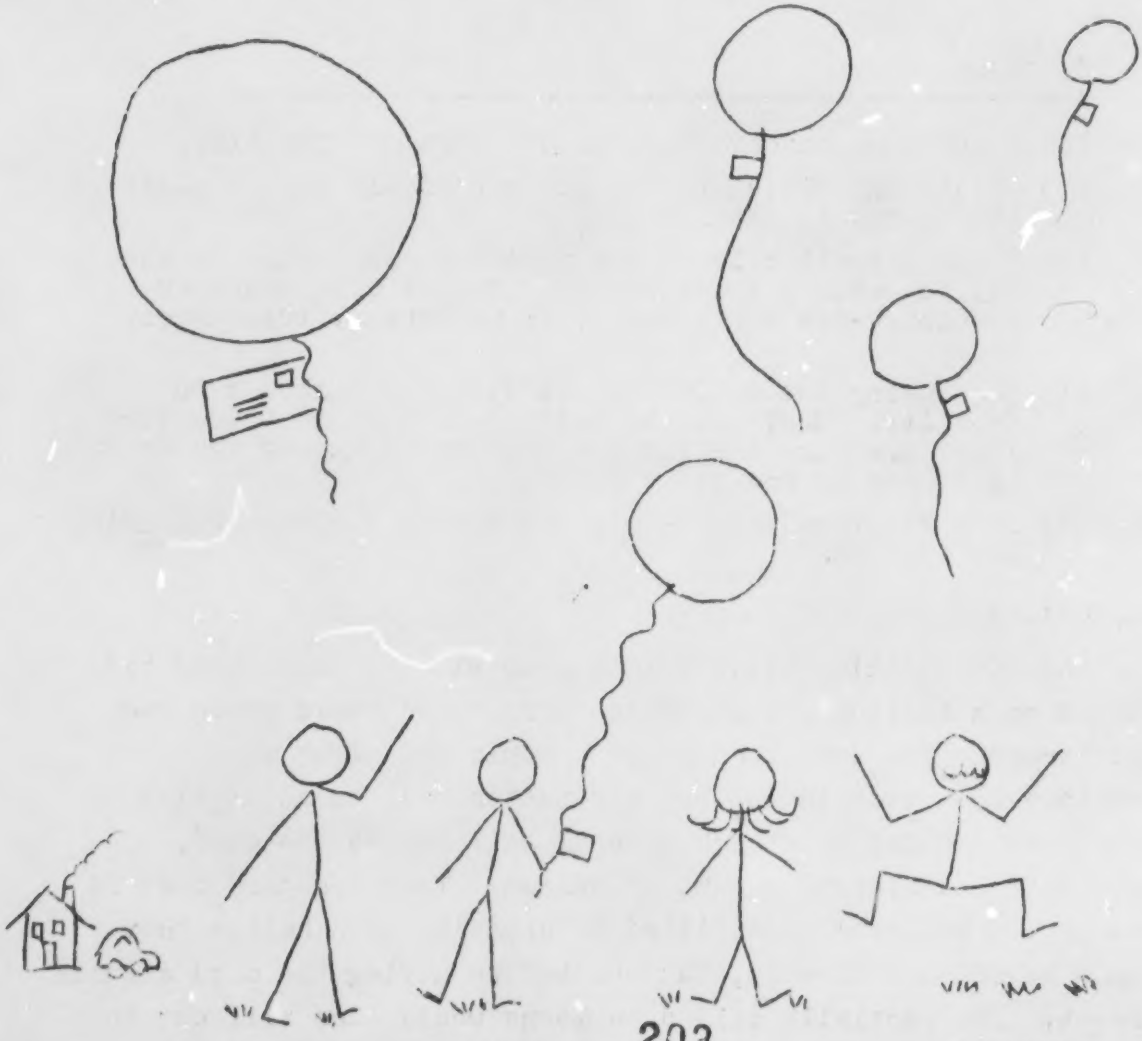
(continued) Balloon Release - Extension

Extensions

the low pressure, wispy upper atmosphere and carry the card still higher. Eventually they too would pop and the final balloon, filled to only 1/3 capacity in Acton, would take over and carry the postcard well into the jet stream! Why not? We haven't heard a response yet but the energetic problem solving was most exciting.

Colloquium

What might happen to the balloon if it encounters hot air above a city? What if it runs into cool polar air? Is it possible that the card could take a very long ride and yet still end up rather close to Acton?



WIND - III. Air Pressure

Background

There are many experiments which can demonstrate that air, although invisible, can exert pressure and has weight. If the class has had prior work with the fluid unit they will be able to apply what they learned about air pressure to a study of wind and weather. If not, this demonstration should be helpful in making this invisible force evident.

So far we have looked at wind from the point of view of thermal factors and rotational deflection. Both considerations produce uneven pressure zones which cause the air to move from high-pressure areas to low-pressure areas. The movement of air (i.e. wind) is not evident if there is no pressure imbalance. Most children find it hard to distinguish air from "nothing". When we say that air exerts a pressure of 15(psi)pounds per square inch, therefore several hundred pounds of pressure on our hands and thousands of pounds of pressure on our bodies, kids ask why they can't feel this force. The reason that the air pressure in our bodies is about equal to the outside hence creating a balance, is unsatisfactory because they are not aware of these conflicting pressures. The answer to this problem is to demonstrate an experiment which involves pressure imbalance and visible evidence of air weight and movement.

Skills

Classifying - different types of pressure imbalance

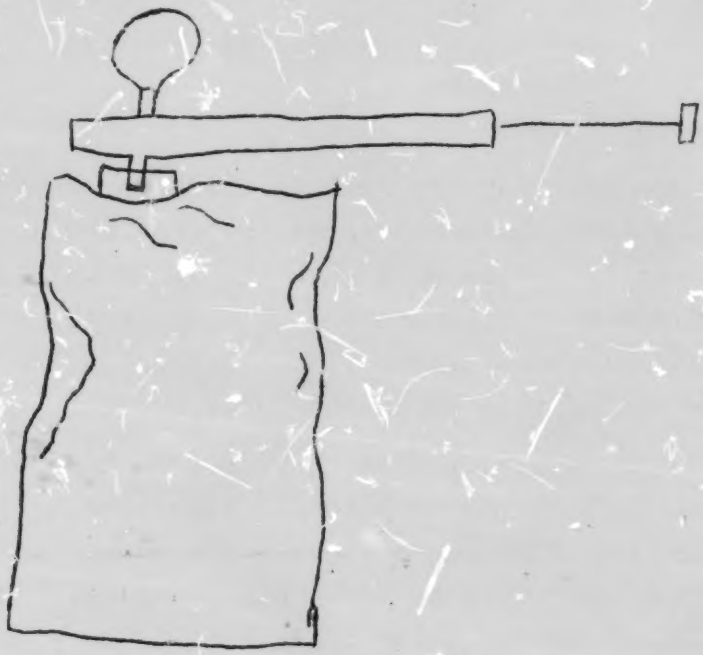
Predicting - the outcome of various parts of the experiment by inferring extensions from the initial experience

Materials

two way air vacuum pump
gallon can (duplicator fluid cans are fine)
one hole cork stopper that fits snugly into the can opening
a medium sized balloon

(contnued)

(continued) Wind - III. Air Pressure



Procedure

(1) Place the gallon can on the table and state that there is approximately 2000 pounds of pressure pressing on the can. The push from the inside balances the push from the outside and the can does not collapse.

(2) Ask what might happen if we withdraw air (reduce pressure) from the inside of the can.

(3) Secure a balloon to the air valve side of your hand pump and insert the vacuum valve into the corked can.

(4) Start withdrawing air from the can and ask the children to notice what happens to the can and the balloon.

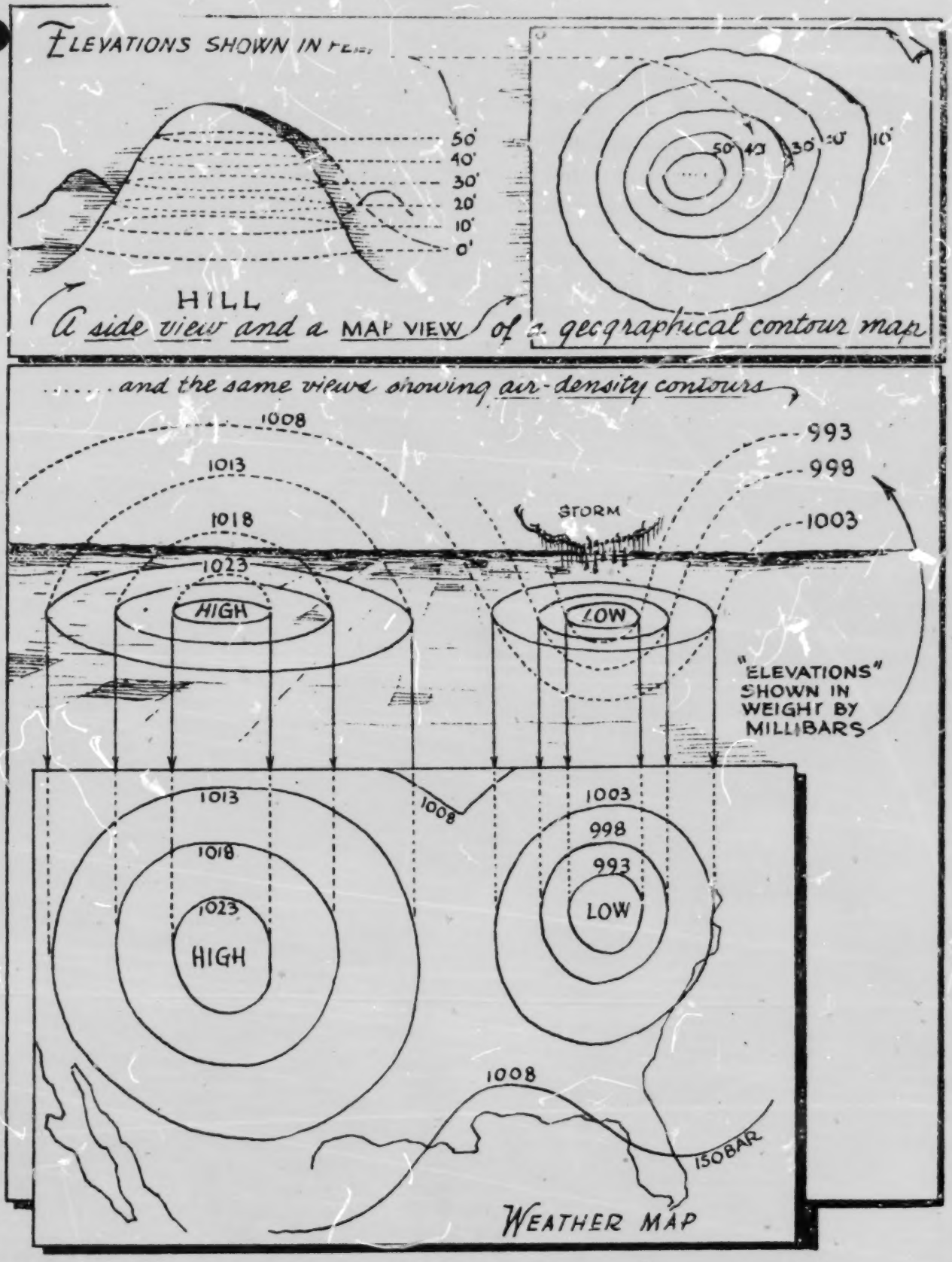
(5) After the collapse remove the pump and reverse the process, i.e. put the filled balloon over the vacuum valve and insert the air valve into the can.

(6) Ask for predictions, start pumping, and observe the results.

Colloquium

What happened to the can in the first part of the experiment? Why do you think this happened? Could you see the results when pressure imbalance occured? Where did the air go that left the can? What happened to the balloon in the

(continued)


ELEVATIONS SHOWN IN FEET
50'
40'
30'
20'
10'
0'
HILL
50'
40'
30'
20'
10'
A side view and a MAP VIEW of a geographical contour map
..... and the same views showing air-density contours
1008
1013
1018
1023
HIGH
993
998
1003
STORM
LOW
"ELEVATIONS" SHOWN IN WEIGHT BY MILLIBARS
1013
1018
1023
HIGH
1008
1003
998
993
LOW
1008
ISOBAR
WEATHER MAP

(continued) Wind - III. Air Pressure

Colloquium

second segment of the experiment? Why? In weather a low pressure area often means bad conditions and possibly storms---does this experiment help you see why? If there were no differences in air pressure would the wind flow?

WIND SPEED AND DIRECTION

Background & Concepts

In our model wind work we have/ will explore the causes of wind and with this microweather exercise we will look at how local winds are altered by objects. It requires that you have already constructed some sort of wind speed and direction device from the options presented. The basic questions we will explore concern whether wind velocity is affected by height and objects, and how wind direction is changed when it encounters an obstacle. The activity here can be divided into two parts, if desired, but I decided to combine them for space considerations. Height platforms, similar to the one drawn in the temperature section, might be helpful. The places you select to investigate are up to you, but it might make sense to study wind flow around corners, in ditches, above and around rocks and bushes, on the roof of the school, under a tree, in the forest, etc. Before starting, check the wind direction and velocity with the National Weather Bureau (936-1234) and mention to the class that you are going to compare their local results with the N.W.B. Ask if they feel there should be a difference. (Select a day with a good steady breeze.)

Skills

observing - wind flow in various locations and
measuring - its speed and direction
predicting - the difference between general and local air flow

Materials

one or two platforms per group
several wind direction and speed instruments per group
data sheets

Procedure

(1) Have a preliminary discussion to review the proper use of the instruments and distribute data sheets.

(2) Start the activity (this part alone could take an entire period) with three locations involving the entire class.

(continued)

(continued) Wind Speed and Direction

Procedure

I suggest a large hill or rock, a bush and a ditch. This will allow us to measure air flow over, around and into various natural objects.

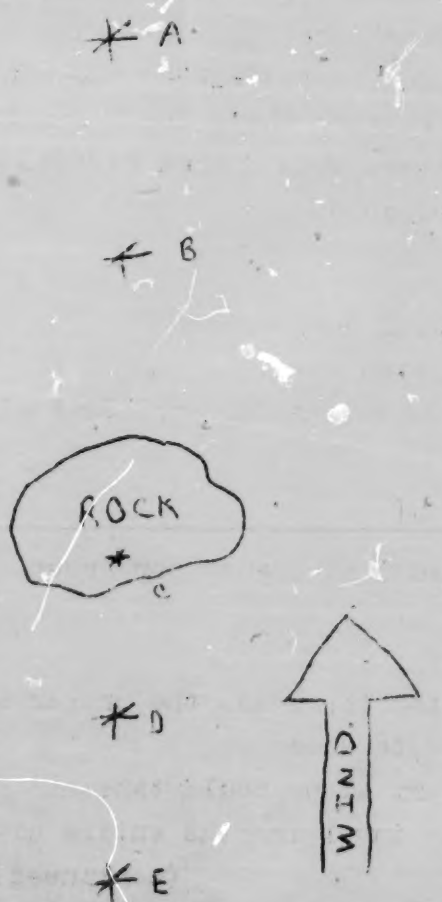
(3) Have the class set up the instruments on the 6 or 7 platforms and place them on a straight line, five feet apart, on the windward and leeward side of the rock. One stand should rest on the rock itself.

(4) Allow time to record the information and chart, or map, the data so it is clear.

(5) Take the same steps, employing the necessary adjustments, with the bush and ditch, and record this data also.

(6) If time allows have the individual teams go off and examine the air flow around one of the microweather stations.

(7) Return all data to class and record on a large chart. A sample chart and map is drawn below.



Height	Direction	Speed
4'	↑	15
2'	↑	14
½'	↑	10
Ground	↗	5

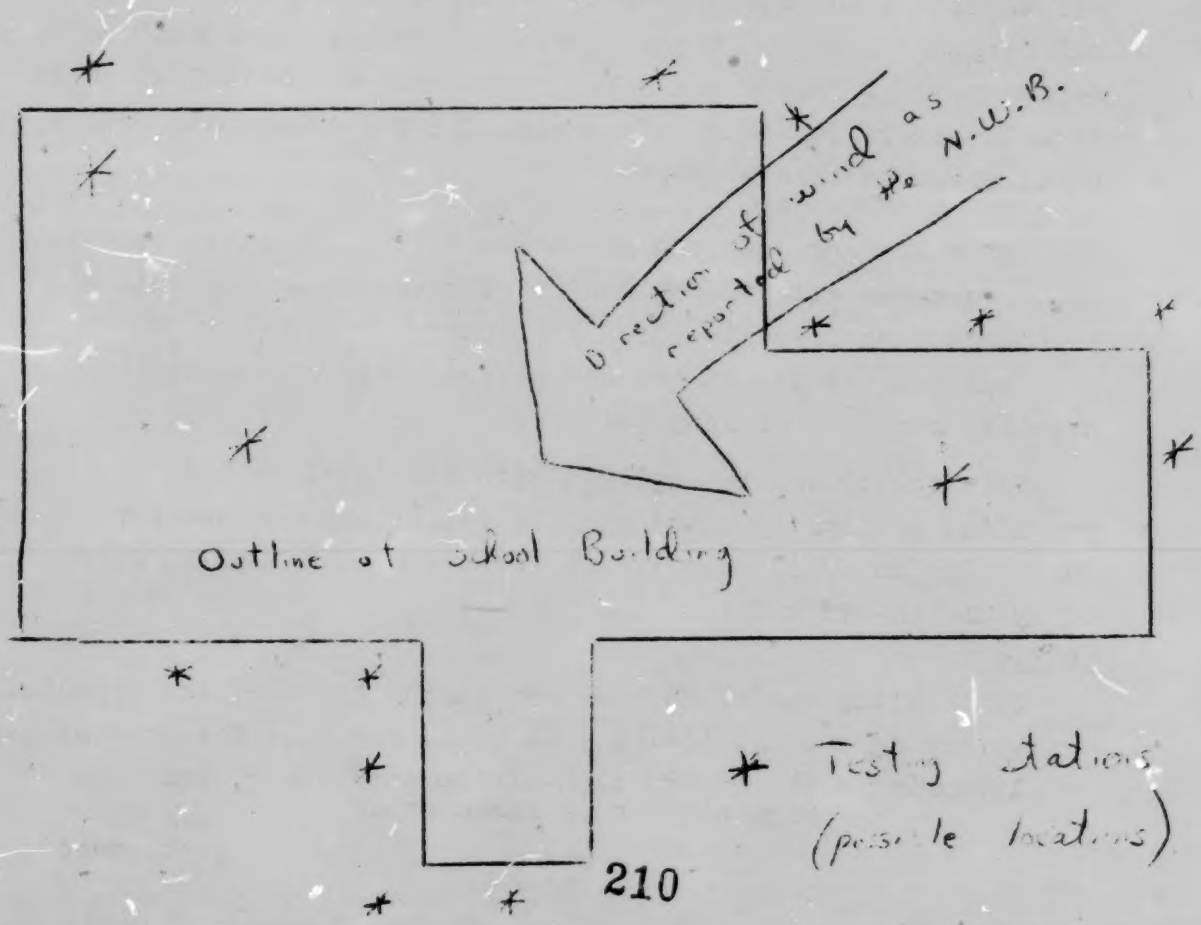
Colloquium

Speed:

At what height did the wind speed seem to be the greatest? The weakest? Did the wind slow down or speed up as it went past or over such objects as the rock or bush? Was it necessary to take average readings with the anemometers? How was the wind speed altered when it went around the corner of a building?

Direction:

How did the wind direction differ from the average when moving around a rock, bush or ditch? Did the forest alter the wind direction?...what about the corner of a building? What was the most interesting wind pattern you observed? How many stations showed a difference from the N.W.B. wind direction report? Did height affect wind direction? Do you think you could draw an air map of the wind flow around the school for all the various winds: N,NE, NW, S, SE,SW,E and W?



MODEL TORNADO

Concepts and Focus

A tornado is the most focused and violent storm in nature. This dramatic model adapted from the "Amature Scientist" in Scientific American, demonstrates the dynamic interaction of an extreme low pressure center and high speed winds. As has been noted earlier, winds are really caused by the uneven heating and cooling of the earth and the flow of air from high to low pressure centers. Tornadoes usually grow out of giant thunder clouds.

The fan obviously represents high speed winds and the vacuum---the low pressure center. The experiments make clear that these forces acting singly are not enough to trigger a tornado. The fan alone is not sufficient to blow the powder off the table and the vacuum by itself will not draw in the material. However, the combination of forces, wind and pressure represented by this model will produce the unique spiral twist of a tornado. In nature of course, all variables (air, water, heat, pressure) are at work.

Large weather patterns are often altered by local terrain, and frequently affects the course of storms. As a result a tornado's path of destruction is blunted by the earth's topology and results in the characteristicly unpredictable hop-skip behavior of many twisters.

This factor can be explored with the model tornado by providing a slightly undulating or relief map surface for the dust. The hop-skip behavior of the storm will then be represented by the on-off swirl of the powder.

Skills

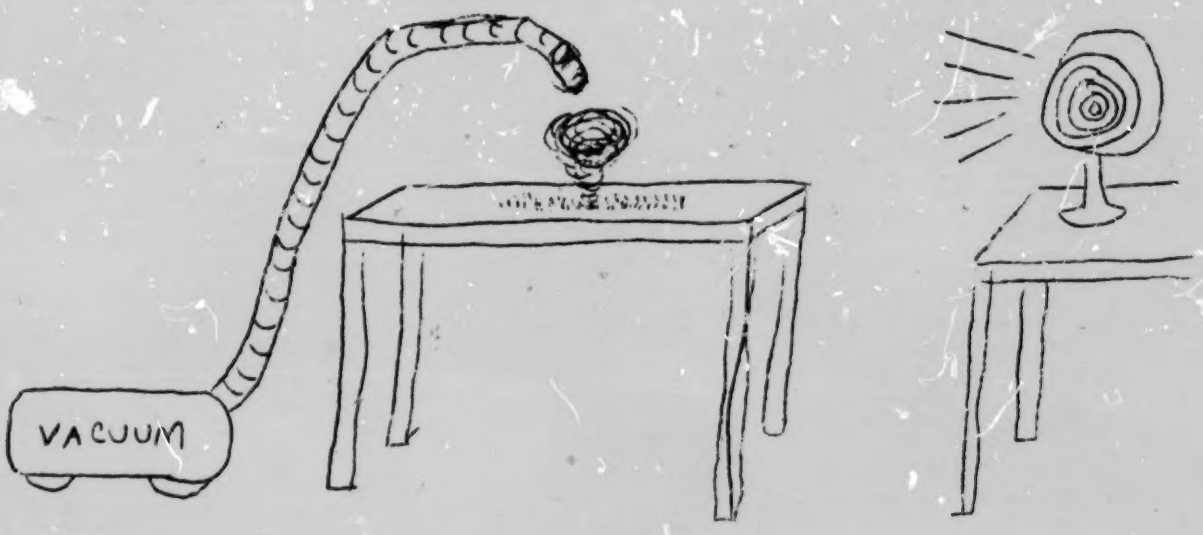
Controlling variables - by sequencing parts of the experiment
Observing and predicting - at every stage of the presentation
Inferring - the interaction of low pressure systems and high winds on a large scale

(continued)

(continued) Model Tornado

Materials

small fan
vacuum cleaner (stronger the better)
flat surface (and relief surface if possible)
light powder - wallpaper paste, plaster of Paris
comb-to spread out the powder



Procedure

(1) Spread out the powder on the demonstration table over a 2' x 2' area---comb to evenly distribute.

(2) Have a student hold the fan approx. 3'-4' away from the powder. Turn the fan on and note that the breeze produced will not disturb the powder.

(3) Switch off the fan and turn on the vacuum --- if you hold the nozzle 1½" - 2" away from the surface it will not disturb the dust.

(4) Turn on both machines at the same time, adjust the angle and speed of the fan, and move the vacuum nozzle slowly across the table 1-2" from the surface. Using long slow sweeps you should be able to create a mini-twister with an upward spiral.

(5) Explore variations (1) adjusting the wind angle and speed; altering the tilt of the vacuum nozzle (3) experiment on an uneven surface which has obstacles and impediments (4) attempting extensions suggested by the kids.

(continued)

(continued) Model Tornado

Colloquium

What does the fan represent? The vacuum?
Do high winds alone produce a tornado?
Can the low pressure center alone produce a disturbance?
What happened when they were combined?
Why? What did you observe that surprised you?

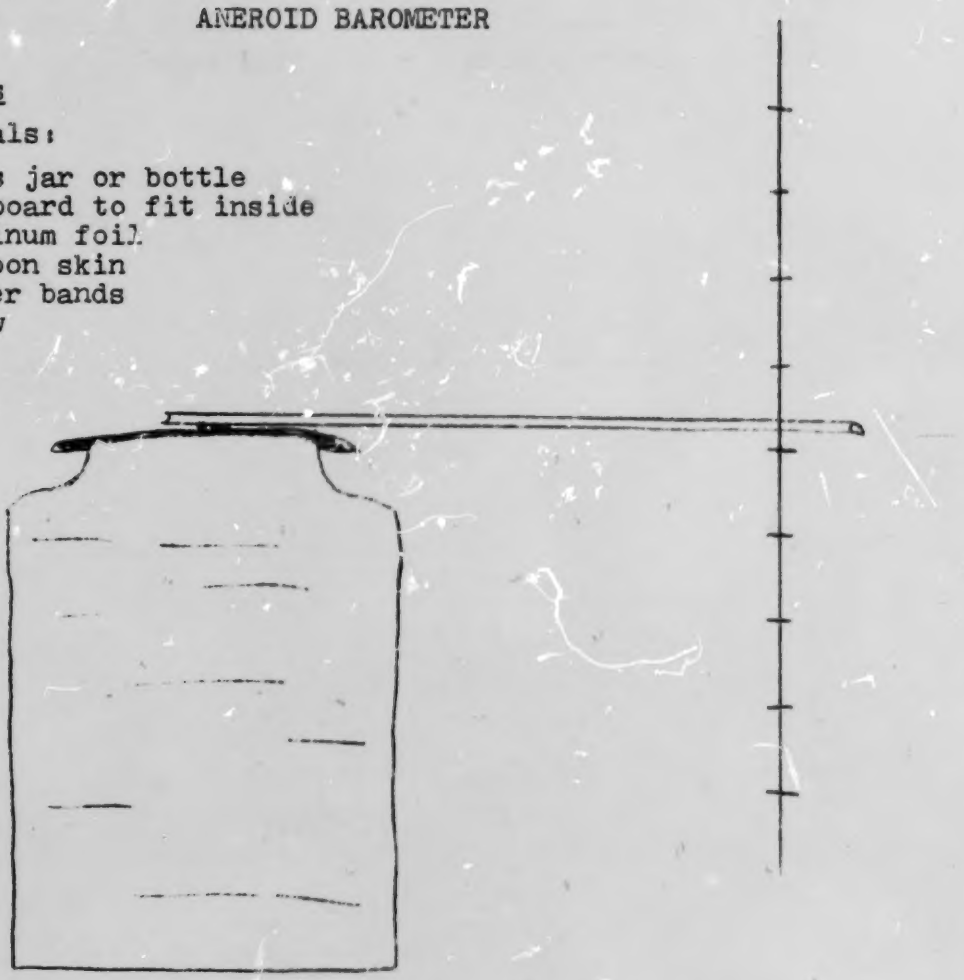
AIR

ANEROID BAROMETER

Instruments

Materials:

glass jar or bottle
cardboard to fit inside
aluminum foil
balloon skin
rubber bands
straw



Procedure

(1) Clean and dry the jar thoroughly and place the cardboard within it to act as an insulator.

(2) Cover the outside of the jar with the foil and stretch a piece of the balloon over the top.

(3) Secure the rubber diaphragm tightly with the rubber bands.

(4) Glue a soda straw to the rubber top so that it extends horizontally from the center.

(5) Hold the straw firmly until it dries.

(6) Flatten the other end by pinching it.

(7) Use a piece of paper as a backdrop for the indicator so you can work out the scale. Call the level mark 0 and use other

(continued)

(continued) Aneroid Barometer

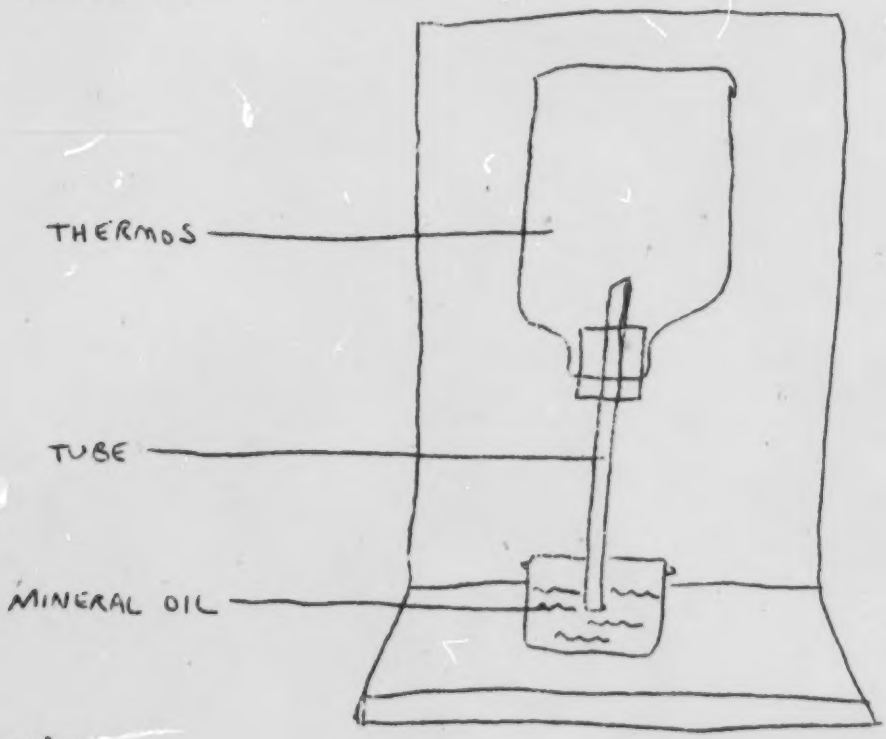
values up and down from this point at 1/8" intervals.

(8) Never use in the sunlight or near a heat source. Check its accuracy with a commerical model.

LIQUID BAROMETER

Materials

clear plastic straw or tube
thermos bottle
one hole cork stopper to fit bottle
small cap or container
cardboard box
wooden box
wooden support
mineral oil



Procedure

Put the straw into the cork leaving six or seven inches free at one end.

(2) Fit the short end of the tube cork system into the thermos.

(3) Turn the thermos, with the tube projecting tube, upside down and secure/support the inverted bottle to a wooden board.

(4) Place the cap under the tube and fill it with mineral oil.

(5) Air pressure on the mineral oil will push the oil up the plastic tube. Mark this point as a reference for observing pressure change.

(continued)

(continued) Liquid Barometer

(6) Cover the thermos with a cardboard box to insur that it is not affected by undue heat or sunlight.

WIND DIRECTION--Pencil Indicator

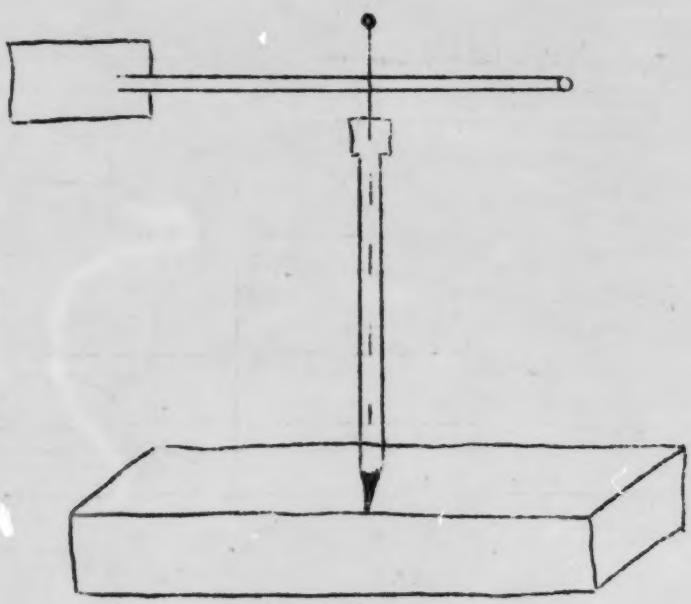
Background

The measurement of wind direction and speed can be accomplished in many ways. The flap of a flag and the Beauford Scale (included) are casual methods which can suffice for general weather observations and predictions. However, for working with micro-climates the small devices suggested below are probably best.

I suggest two instruments per category, but only one of each is needed. These have been adapted from various sources and modified through experience and trial. Select the ones you feel easiest to construct and maintain.

Materials

wood block base
pencil with good eraser
straight pin
straw
cardboard indicator (1" x 2")
sewing needle with diameter slightly wider than that of the pin



(continued)

(continued) Wind Direction-Pencil Indicator

Procedure

(1) Drill a small hole in the wood base and snugly insert the pencil.

(2) Insert the needle into the middle of the straw to prepare the pivot for the pin.

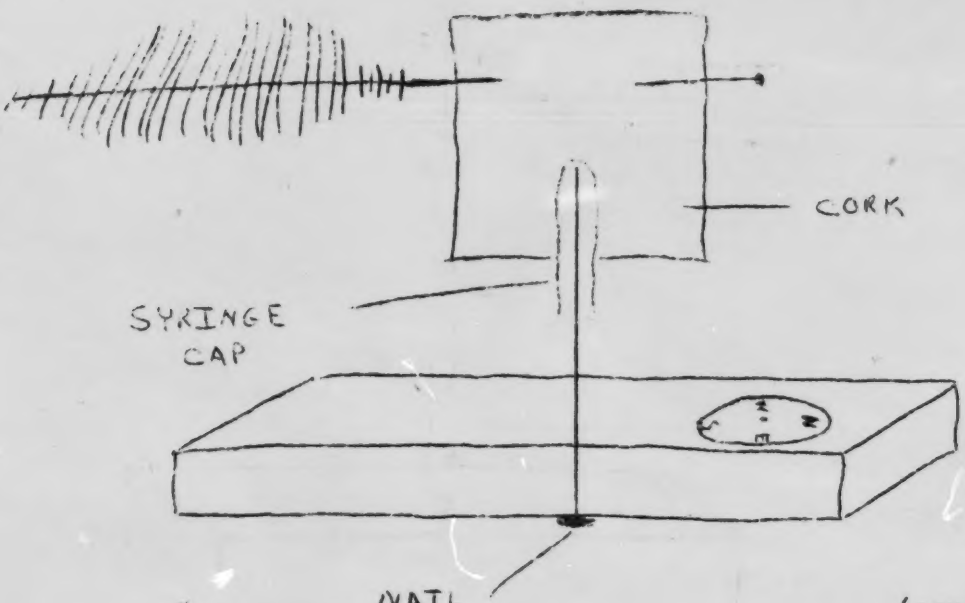
(3) Place the pin into the same hole and then into the eraser.

(4) Staple the indicator to one end of the straw and add a bit of clay to the other end to keep an easy balance.

WIND DIRECTION-Feather Indicator

Materials

wood block base
#8 cork
long plastic syringe cap
3" feather
3" finishing nail
small nail or tack
small plastic compass



(continued)

(continued) Feather Indicator

Procedure

(1) Push the plastic tube into the bottom of the cork until it fits snugly.

(2) Drive the finishing nail through the middle of the block at right angles to the base.

(3) Push the feather indicator into the side of the cork and mount the cork on the nail.

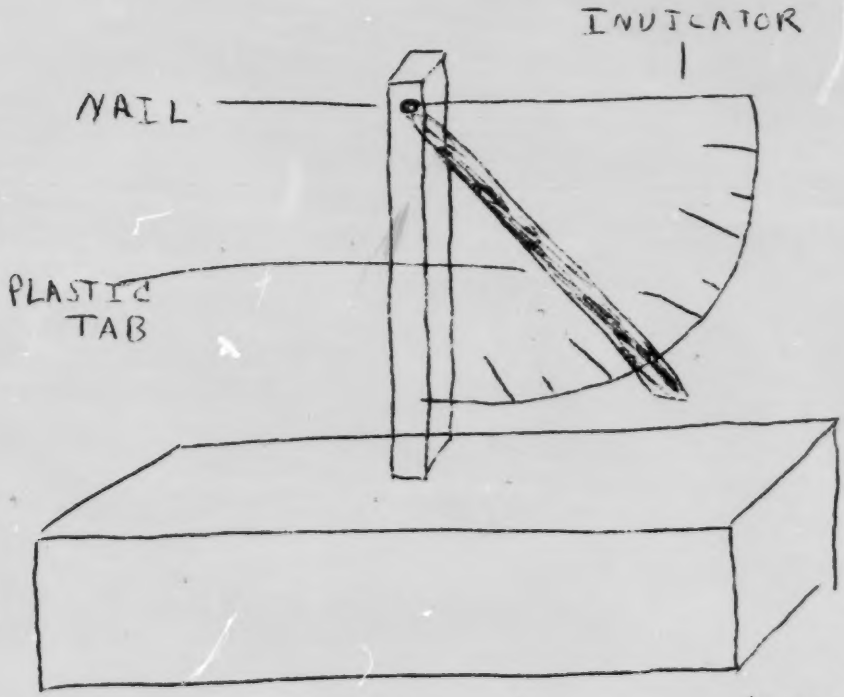
(4) Use small nails or tacks to insure the balance and easy spin of the system.

(5) Glue a small compass to the base of the block.

WIND SPEED FLAP INDICATOR

Needed:

wood block base
dowel (½" diameter) and 4" long
cardboard background and tacks
nail 3½" long
2" x 3" plastic flap (formica samples are fine)



(continued)

(continued) Wind Speed Flap Indicator

Procedure

(1) Drill a hole in the block and insert the dowel.

(2) Hammer the nail through the dowel about ½" from the top.

(3) Hang the indicator flap from the rail with string or fishing wire.

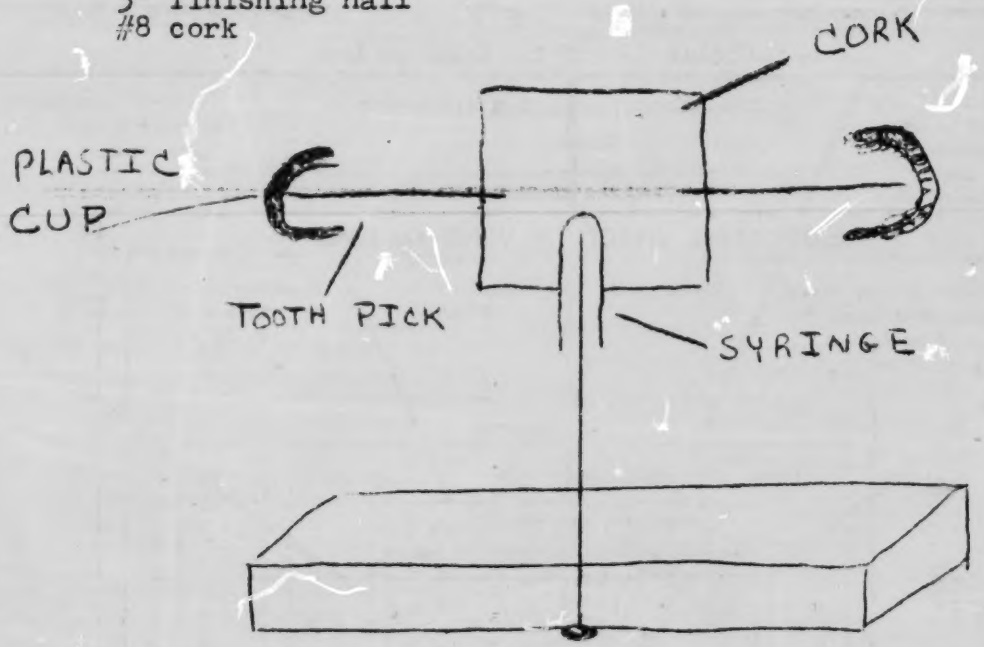
(4) Tack the cardboard background onto the dowel and adjust it by making equally spaced marks in a sequence to produce a scale.

(5) Take the instrument for a car ride on a windless day and note the amount of flap deflection for 5, 10, 20, 30, 40 mph. This will calibrate the scale and allow reasonable accurate readings of wind speed.

WIND SPEED CUP INDICATOR (Anemometer)

Materials

wood block base
plastic syringe tube
small plastic cups & tooth picks
3" finishing nail
#8 cork



Procedure

(1) Push the plastic tube into the bottom of the cork.

(2) Drive the finishing nail through the middle of the block.

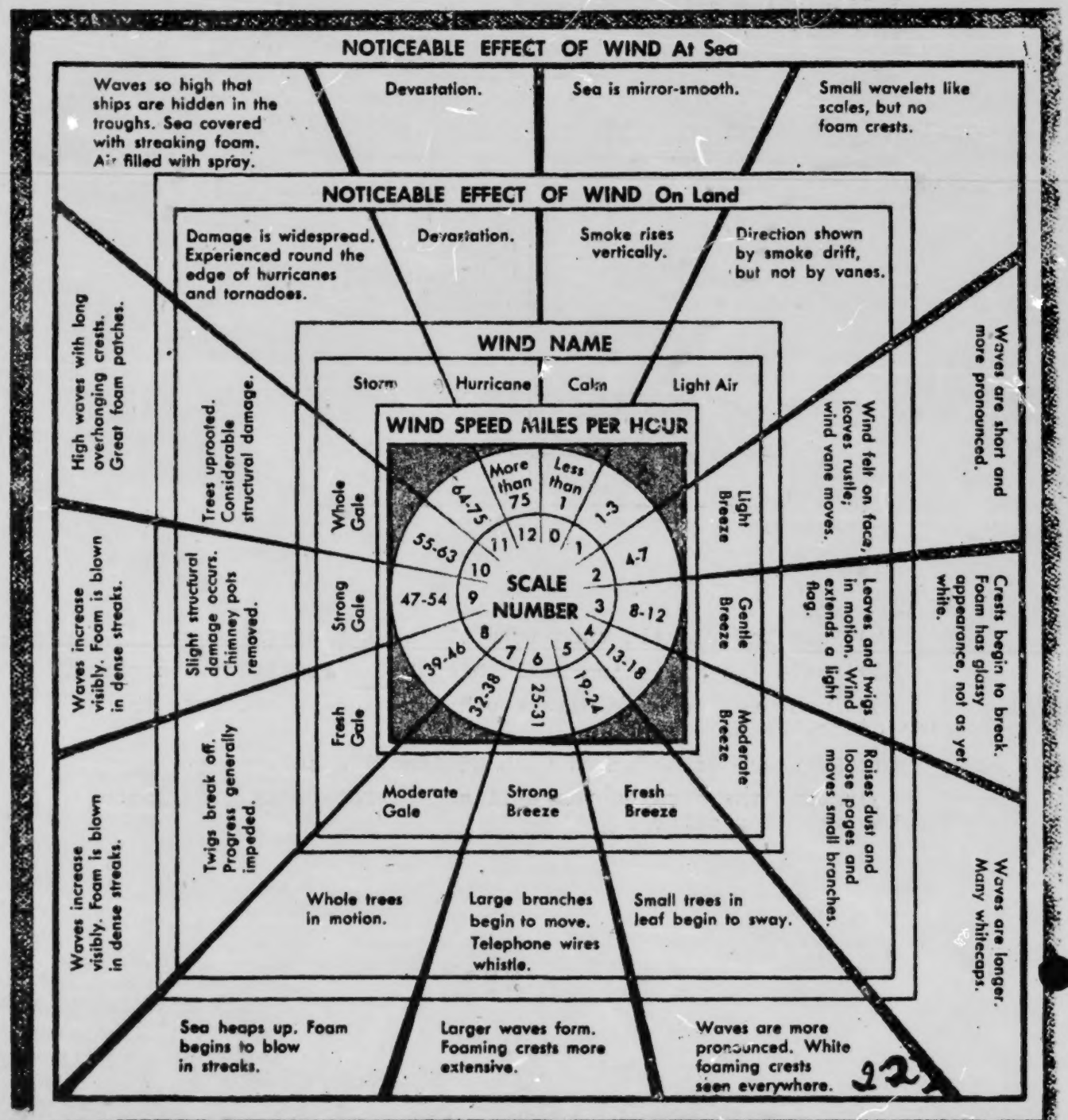
(3) Puncture the cups with toothpicks and insert into the side of the cork.

(4) Mark one of the cups with distinctive color.

(5) Mount the cork on the nail and calibrate as I suggested for the flap indicator.

THE BEAUFORT SCALE

MANY years ago, before modern weather instruments were used, a man named Sir Francis Beaufort made up a scale to describe the force of winds by the way they acted over land and sea. Here is a form of this scale. How many of these wind effects have you felt? Scale numbers indicate wind strength.



WEATHER FORECASTING

Background

This activity should probably be done near the end of the unit since it necessarily involves all aspects of weather. It can be handled in several different ways depending on the instruments at hand and the number of variables included. Beyond this consideration I will suggest both individual and group prediction experiences enabling all to compare their forecasts with others. It should be pointed out that the efforts of your class regarding weather prediction will be equal to that of the United States Weather Service in terms of scientific intensity and thoughtful probing. Both groups combine personal observations and instrumental data with careful analysis in order to forecast the weather---it's just that the U. S. Weather Services has a greater quantity of technical resources than your class. It is important that the work of your neophyte meterologists be recognized as scientifically sound and legitimate given the methods available.

Skills

observing - weather conditions
measuring - weather conditions with various instruments
recording - the collected data
predicting - potential conditions

Procedure

(A) Experiment - - Personal Forecasting

Make a chart or work sheet with the following categories for consideration: date, time, temperature, pressure, moisture, clouds, wind direction and speed, precipitation, "My Forecast", and a "What happened?" at the end. Each child should be asked to select three days over the course of a week during which time they fill in the chart with the proper data and write out their forecasts. Results can be shared and discussed by all. Was anybody right all the time? Was anyone fooled consistantly?

(continued)

(continued) Weather Forecasting

(B) Experiment - - Local Forecasting

This experience can be done during one week. It basically involves compairing the class group prediction with that of the U. S. Weather Service. This can be done by employing the following materials and procedures:

Materials

1 large (poster size) classroom weather chart with same categories as above including a section for the "U.S.W.B. Forecast"

tape recording of the U.S.W.B. forecast taken just before the class prediction

weather station instruments

Procedure

(1) Have one or two kids call the Weather Service in Boston (936-1234) and record the latest hourly forecast. These two must then return to the class but promise not to leak their high level intelligence data until the class predictions are completed.

(2) Have the class do observations and check instruments so the weather chart can be filled with the necessary information, up to the forecast section.

(3) Given the same data ask the class to generate some possible weather predictions for the evening and following day. Usually a class will produce two or three possible models, each with ardent supporters. After discussion, during which time each position is aired and explained, check to see if there is a growing consensus for one view. If there is, list this view as the majority opinion and then list the minority options below that.

(4) How does the class prediction stack up against the professional weather service? Have the recorders switch on the tape and listen to the detailed report and forecast.

(5) The following day compare all predictions with the actual weather that occurred.

(6) Continue for one week---longer is really not necessary- the limited span makes the experience more intense.

(continued) Weather Forecasting - Weather Maps

(C) Experiment

Background

This experiment involves reading real weather maps and doing large scale predictions. Many of you might want to avoid this type of exercise and concentrate on more tangible, local experiences.

If you look at a real weather map or the type published in the "N. Y. Times" (the "Globe" effort is too simple to be of any value), you will note that it is replete with scales and symbols. These are actually rather easy to understand with experience and practice, allowing the reader to see developing weather long before it affects his/her locale. Using the symbol sheet included in this unit and a general knowledge of wind flow and high/low pressure importance, your class should be able to do weather map forecasting.

Procedure

(1) Pass out an outline map of the U.S. that includes most of the common weather symbols: temperature, isobar pressure lines, fronts, wind speed and direction (Beaufort Scale), conditions and precipitation. Make up your own weather for the map.

(2) Along with this basic map list a series of questions that relate to the imaginary weather you have created. What type of front has just passed through Portland? Will Boston probably have rainy weather tomorrow? What city is nearest the low pressure center near the Gulf of Mexico?

(3) You might reproduce a newspaper map for the day in question and focus your questions on the current situation. The class can then try to predict nation wide weather for a couple of days and check the results daily.

(4) Perhaps the kids could produce weather maps for imaginary places and exchange them with each other. It would allow them to take into account all sorts of topological features such as mountains, deserts, oceans, valleys, islands, etc.---the possible activities in this area are really endless.

(continued)

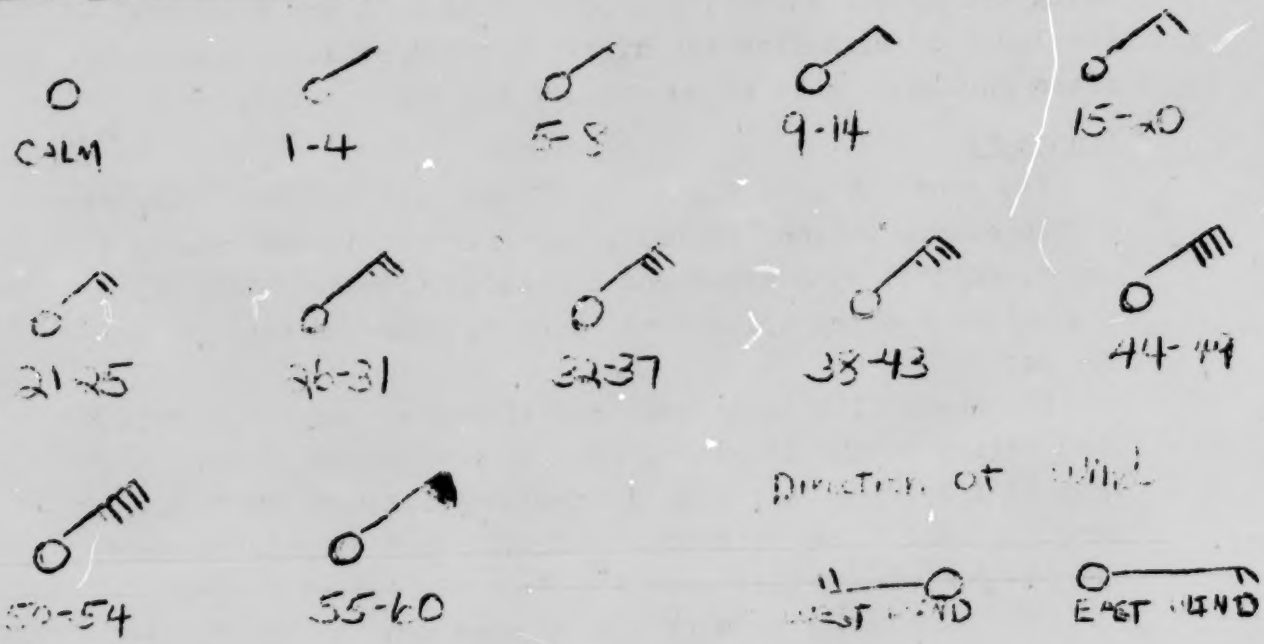
WEATHER MAP SYMBOLS

TEMPERATURE – listed in degrees F or C°

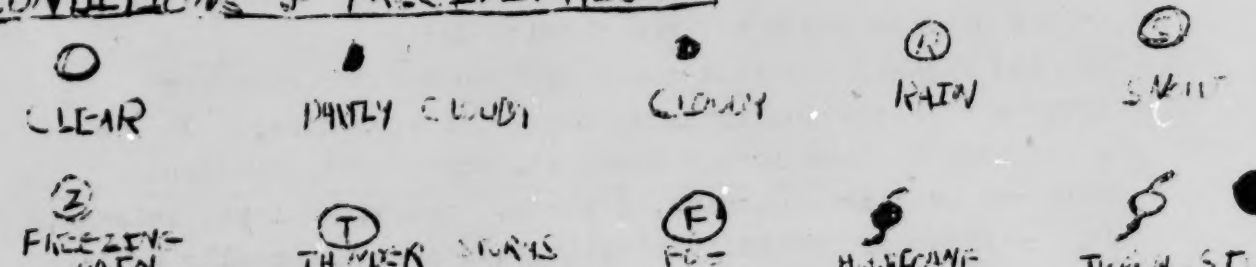
ISOBARS – pressure lines
high wind low pressure centers

FRONTS Cold
Warm
Stationary

WIND SPEED & DIRECTION
BEAUFORT SCALE –



CONDITIONS & PRECIPITATION



THE HOSPITABLE PLANET EARTH

For the last few years ecologists have stressed how delicately humans are perched in their ecological niche. Stephen Dole, a systems analyst has considered the problem on an even grander scale: how, from the very beginning, basic planetary physics determined the roles life could play on earth.

Although the physical evolution of the earth is not fully understood, Dole has applied what we do know to various "model earths" that differ slightly from our familiar planet. Suppose, for example, that when the solar system was formed, the earth had accumulated twice its present mass, altering its density and giving it a surface gravity 1.38 times normal. This increase in mass and gravity would squeeze the interior more, heating it to higher temperatures and forcing lava to percolate more readily upward. In turn, the quickening flow of gases and water vapor from volcanoes would produce a thicker atmosphere and larger oceans. The air would probably not be substantially different; the primordial atmosphere of methane, ammonia, and carbon dioxide would have eventually evolved, in concert with plant life, to its present state. Marine life would also have developed along the lines we know, but with more water forced to the surface through volcanoes, the oceans would grow. Our continents would shrink; perhaps there would be only scattered island chains.

(Double MASS)

To offset the increased gravity, plants would be shorter and trees would have thick trunks and stubby branches. Short, stout land animals with large feet would probably play the same basic roles we know. But birds might not have evolved at all, since the ability to fly is based on a delicate balance of gravity, air density, and the amount of bone necessary to support the bird.

Even the appearance of the land would be changed. Since they would exceed their structural support, mountains could not thrust so high. Water would fall faster, hastening erosion and carving deep canyons and gullies. Ocean waves would be shorter and clouds lower. Other things, such as the composition of the earth's crust, size of the ice caps, period of the moon, and the earth's magnetic field would be changed. Certainly, even if most of the accidents of evolution were repeated, the resultant humans would be substantially different from ourselves. They would be short, stocky, more muscular, and probably less graceful; more subtle changes in behavior and outlook would follow.

Turning the problem around, what if earth had evolved with half its present mass? With a surface gravity of 0.73g., there would be less water produced by volcanic action, a thinner atmosphere, reduced erosion (because water would not fall as fast), and probably a greater profusion of bird life. Animal skeletons would be lighter, trees taller, and, again, humans would certainly be different. They would be taller, with smaller feet. They might even have evolved to use trees and ground jointly as their ecological niche, instead of specializing as foraging land creatures.

(Half MASS)

(continued)

(continued) Weather Forecasting- Weather Maps

Colloquium

Each of the exercises above allows kids to view their prediction efforts as legitimate within the scope of the instruments used. As a result the central colloquium question becomes, "Did I have enough information to make good predictions? In what respect were our instruments accurate? How might they be improved? Was the Weather Service alway right in its predictions? Could there be some factors that they are overlooking?

(continued) The Hospitable Planet Earth

Many aspects of planetary physics would make for even greater differences. For example, the earth's axis is inclined at an angle of 23.5 degrees to the plane of its orbit around the sun. This gives us our winters and summers, as one hemisphere or the other is succesively turned toward the sun. What if this angle were increased? If the angle were 60 degrees, but day length the same, seasonal weather changes would be intolerable. Men could live only in a narrow belt within 5 degrees of the Equator; during most of the year the rest of earth would be too cold or too hot. Life might do fairly well in the oceans, but it would not evolve rapidly and successfully on land.

(60° Axis)

Conversely, changing the angle of inclination to zero degrees would not have influenced matters greatly. There would be no seasons; weather would be humdrum and boring. Near the Equator, the temperature would be considerably higher than it is now, and people would avoid living near it. The poles, however, would be warmer and men could live closer to them.

(0° Axis)

Our climate is critically determined by the amount of sunlight that reaches the surface of the earth. To illustrate how precarious the balance is, suppose the earth were 10 percent closer to the sun (which would probably alter our atmospheric evolution, too, but for simplicity we'll neglect that complication). Even this small change would mean that only 20 percent of the world would be inhabitable by humans. The Equator would be a torrid, impassable band around the planet, leaving only two narrow regions near the poles where man could live.

Closer to the sun)

Evolution on the land could even proceed independently in the two regions. Specialized land forms, which could fly high over the Equator and thus make use of both regions, might evolve, but overland travel would be impossible. Conceivably, man could evolve in one region and develop an entire civilization without knowing that there was another half of a planet available to him. (This situation would be roughly comparable to what happened in our history--until 500 years ago most of civilization knew nothing of the Americas.) The livable land f of this hotter earth, however, would be scarce, because polar caps would not have formed, resulting in larger oceans.

We would also toy with earth's day. A shorter day, say, three hours, would not make much difference in the habitability of our planet. It would, however, have interesting side effects--warmer nights and cooler days, probably more tumultuous weather, higher winds, and, because of the higher angular velocity of rotation, a slight apparent change in gravity between the Equator and the poles.

Short) Day)

Making the day longer, 100 hours for example would be disastrous. Few forms could live on land, because they would roast in the day or freeze at night.

Long) Day)

It is not surprising that the changes investigated are all for the worse. We have evolved to fit our world, just the way it is, and no other planet--hypothetical or otherwise--is likely to suit us as well.

SWINGS, SWAYS, AND THE PENDULUM

An Extension of the ESS Pendulums Unit

Intended for Grade 4 but the unit can be used on the 5th and 6th Grade level

Part of 1976 R & D for
Science and Social Studies
Acton Schools

Eugene F. Trainor

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SWINGS, SWAYS, AND THE PENDULUM

I. Introduction to Swings, Sways, and the Pendulum---

This study is offered as a supplement to the ESS Pendulum Unit.

Section 1. "The Pendulum: Major Variables"

The first section "The Pendulum: Major Variables" is a three parts study focused on the variables which may or may not affect the number of round trips (periods) a pendulum will travel in a set time. This section designed originally by Dr. Maurice Belanger of Harvard University as a research project has been adapted for classroom use.

In the first part of the Belanger project a pretest is provided. Students observe a dormant pendulum and predict what will happen to the number of round trips when the four variables are manipulated.

In the second part children modify the action of four variables:

1. string length; 2. push; 3. the weights on each pendulum bob; and 4. the angle of release. In the process of controlling the variables and recording the data from their experiments with each variable children should begin to negate the influence of all other variables on the number of round trips except one: the length of the pendulum. By no means should children be told this. The data will reveal it.

The final part of this study is given at the end of the unit. It is the post test and; it provides an assement in the form of a practicum of the learnings of children in the unit. Chart shells and recording sheets are included.

Section 2. "Swings, Sways, and the Pendulum: An Extension of the ESS Pendulum Unit"

The second sectinn advances the focus of the tasks to the relation between short and long pendula. Eventually, the child is encouraged to find a rule, a principle, or a formula,

(continued)

(continued) Section 2. "Swings, Sways, and the Pendulum"

if he can, which establishes the relation between the long and short pendulum where one makes twice as many or three times as many round trips as the other. It includes the verbatum statements of children made in a colloquium.

Finally, a series of pendulum systems are pictured which children might like to try.

II. The equipment and supplies necessary for a class of thirty students.

Children could work in clusters of two pairs to share equipment and for discussion purposes.

15 - 4' lengths of pine strapping 1"x 2" or 1" x 3" pine strapping. Do not use spruce or hemlock--it tends to warp

1 - Electric clock with highly visible sweep second hand for timing. (optional)

2 - spools of braided fishing line--

10 - 12lbs. test (100 yards of line)

1 - ball of cord

15 - Protractors

3 - rolls of masking tape--1 inch--

7lbs. #5 Lab grade

One hole rubber stoppers

Size	Top Diamenter	Botton Diamenter	Hole Diamenter	N/lbs
#5	27mm	23mm	5mm	29

15 meter sticks

60 paper clips

1 - Box of gram weights

III. Preparatory information: It is important for you to perform these tasks before the children do. If you do, you will be in a better position to appreciate some of the students' problems.

Since the students are not going to work with precision instruments, they may find it difficult to obtain exactly the same results from trial to trial. In order to minimize experimental error you may wish to tell children to hold constant all variables except the one to be measured, ie, if you are

(continued)

(continued) Preparatory information

changing the number of weights on the pendulum bob, then the string length, the angle of release, and the push should not be changed.

You may need to give instruction in the use of protractors for measuring angles prior to beginning of Part 2.(See Appendix....p. 18)

To Duplicate: Chart shells and recording sheets for children may be pulled out and use with thermofax masters.

IV. Suggestions for Teaching Schedules

Plan A--Introduce unit with "Pendulums: Major Variables" pretest. Follow with activies and colloquium. Reserve the post test for the end of the entire unit.

Plan B--

1. Introduce first lesson with "Swings, Sways, and the Pendulum: An Extension".

1) Lesson # 1 - The First Explorations ...p.23-26

2) See also ESS Pendulums - p. 11

Lesson # 2 may require severll activity periods

1) From Swings, Sways and the Pendulum:
Lesson # 2 "Comparing Long and Short Pendula" p. 27-31

2) See ESS, Pendulums pp. 12-13-14 also p 19.

Lesson # 3

1) Lesson #3 from Swings, Sways and the Pendulum "Can you set up one pendulum to make twice as many round trips as the other? p. 32-36

2) From ESS Pendulums - pp. 19-20

Lesson # 4

1) Lesson # 4 from Swings, Sways, and the Pendulum p. 37-42

Lesson # 5

1) Lesson # 5 from Swings, Sways, and the Pendulum p. 43-47

Lesson #6, 7, 8

Follow directions for lessons 6, 7, 8 in Swings, Sways and the Pendulum" p. 48-50

V. "The Pendulum: Major Variables"

Suggested procedure for using this section.

In general this is a series of closely related activities not easily separated for use with the other sections of this unit. It is suggested that it be taught at the beginning of the unit with the post test administered at the end of the unit.

It may also be used with upper grade children particularly sixth grade students.

The number of separate activity periods:

Part 1. Single session

Part 2. One to four sessions. It is most effectively used in one session of about one hour when the necessary preparation has been made to set up equipment, furnish charts and to establish clear directions.

Part 3. Post test and Colloquium: A single session.

The Pendulum: Major Variables
Part 1
Activity 1
(Pre-test)

Skill: Predicting

Behavior: Confronted with a situation and a related model, he makes predictions based upon that mode.

Objective: To determine knowledge student has about behavior of pendulum and to form hypotheses about it.

Materials: 1. "Directions for Teacher Pre-test and Post-test" (See Appendix, page
2. "Diagram for Pre-test and Post-test apparatus"* (See Appendix, page
3. "Pre-test and Post-test" -- one copy for each child
4. Box of weights with hooks
5. Nylon fish-line
6. Support bar (wood strapping)
7. Masking tape

Background Information: Do not allow questions about the pendulum to be asked. The question posed before the group may invalidate the pre-test.

Procedure: 1. Prepare apparatus for pre-test
2. Administer pre-test. Results of the pre-test should not be given to students.

Caution: At no time during the pre-test do you actually allow the pendulum to swing freely except during demonstration prior to pre-test. However, when students are asked to compare round trips when angles of release are different, you do pull the pendulums back but without ever releasing them.

* To Duplicate: Simply use with a Thermofax Master when you wish to duplicate the written materials.

The Pendulum: Major Variables
Part 2
Activity 1
(String length)

Skill: Predicting

Behavior: Given a repeated event, he measures, records, and predicts the measurement of the next occurrence of the event.

Prerequisite: 1. Skill: Measuring
Behavior: a. Computes averages from repeated measurements of the same object or phenomena.
b. Uses a protractor

2. Pre-test (Part 1, Activity 1)

Objective: To investigate whether the change in string length causes a change to occur in the number of round trips the pendulum makes in 15 seconds.

Materials: Support bar (wood strapping); fish-line; cord; masking tape; rubber stoppers; protractors; record sheet (see Appendix, page 19 "How to Measure and Fix the Angle" (see Appendix, page 18.

Background Information: A round trip or period of a pendulum is the movement of the pendulum from the point of release to the farthest point away from the point of release and then back again. "Away and then back again" would be one period or one round trip.

Procedure: 1. Assist students in use of protractor to determine angle of pendulum release. You will notice the "up and down" string on the diagram "How to Measure and Fix the Angle." This is the base line from which the angle of release is measured with the protractor. The second string should be set at an angle of 10 degrees and taped to the floor. Once this is done the "up and down" string can be removed. This procedure will eliminate the need to reset the second string for each trial.

2. Pass out record sheets (1 for each student) and equipment and allow students to perform activity.

3. Do not discuss results with children other than to deal with "significant differences" (see Preparatory Information" page and assist with averaging.

The Pendulum: Major Variables
Part 2
Activity 2
(Weights)

Skills: Measuring

Behavior: Repeats measurements of the same objects or phenomena and visualizes the range of the measurements.

Prerequisite: Part 2, Activity 1.

Objective: To investigate whether the change in the number of weights acting as bobs causes a change to occur in the number of round trips the pendulum makes in 15 seconds.

Materials: Support bars (wood strapping); fish-line; masking tape; rubber stoppers; protractors; record sheet (see Appendix, page 20. "How to Measure and Fix the Angle" (see Appendix, page 18

Background Information: None

Procedure: 1. Students use protractors to set up a 10 degree angle of release for pendulum.

2. Pass out record sheets (1 for each child) and equipment and allow students to perform activity. They will be counting the number of round trips a pendulum makes when the manipulated variable is the number of weights on the bob.

3. Do not discuss results with children other than to assist them in computing averages.

The Pendulum: Major Variables
Part 2
Activity 3
(Angle)

Skill: Recording

Behavior: Records repeated measurements and calculations of averages.

Prerequisite: Part 2, Activity 2.

Objective: To investigate whether the change in the angle at which the pendulum is released causes any change in the number of round trips in 15 seconds.

Materials: Support bar (wood strapping); fish-line; masking tape; rubber stoppers, protractors; record sheets (see Appendix, page 21 "How to Measure and Fix the Angle" (see Appendix, page 18.

Background Information: None

Procedure: 1. Pass out record sheets (1 for each child) and equipment and allow students to perform activity. Students will be counting the number of round trips a pendulum makes when the manipulated variable will be the angle of release.

2. Do not discuss results with students other than to assist in computing averages.

The Pendulum: Major Variables
Part 2
Activity 4
(Push)

Skill: Explaining

Behavior: Repeats experiments to get more reliable data.

Prerequisite: Part 2, Activity 3

Objective: To investigate whether pushing the pendulum at the moment of release will cause a change in the number of round trips it will make in 15 seconds.

Materials: Support bar (wood strapping); fish-line; masking tape; rubber stoppers; protractors; records sheets (see Appendix, page 22); "How to Measure and Fix the Angle" (see Appendix page 18).

Background Information: None

Procedure: 1. Pass out record sheets (1 for each child) and equipment and allow students to perform activity. They will be counting the number of round trips a pendulum will make when the manipulated variable is the degree of push at time of release.

2. Do not discuss results with children other than to deal with "significant differences" (see Preparatory Information" page 4-5and to assist with averaging.

The Pendulum: Major Variables
Part 3
Activity 1
(Post-test)

Skill: Explaining

Behavior: Asks for explanations and waits for answers provided by investigation.

Prerequisite: Parts 1 and 2

Objective: To find out if students base answers to post-test on data collected during experiments of Part 2

Materials: 1. "Directions for Teacher for Pre-test and Post-test" (see Appendix, page 14.
2. "Diagram for Pre-test and Post-test Apparatus" p. 15
3. "Pre-test and Post-test" (see Appendix, pages 16-17, one copy for each student.
4. Box of weights with hooks
5. Nylon fish-line.
6. Support bar (wood strapping).
7. Masking tape.
8. Copies of records sheets from Part 2, Activities 1-4.

Background Information: If you administer the post-test without allowing children to use their records sheets from Part 2 and they miss certain questions on the test, it may be due to forgetting the results from Part 2 rather than disregarding them. The results of the post-test will be more valid if students have their record sheets to refer to while taking the test. When administering the post-test, observe the same conditions you did for the pre-test, i.e., not actually swinging the pendulum and not answering questions about the pendulum.

Procedure: 1. Pass out record sheets from Part 2, Activities 1-4.

2. Pass out post-test and administer it in the same manner as the pre-test using same questions and apparatus.

The Pendulum: Major Variables
Part 3
Activity 2
Colloquium

Prerequisite: Post-test

Objective: To discuss the results of experiments using a format. To determine which students, if any, ignored data and retained preconceptions indicated in pre-test.

Materials: Record sheets from Part 2; post-test.

Background Informatinn: Teacher may decide which to use or perhaps let students choose the level.

Procedure: 1. Let students prepare reports using formats outlined above.

2. Students can then give reports to a small group or whole class. Teacher and students can decide.

3. A discussion might ensue after the reporting touching some of the following areas.

a. Compare answers or pre-test and post-test.
b. Determine how many or who had different answers on post-test than they had on pre-test.
c. "How did data collected in Part 2 affect your thinking about what causes a change in the number of round trips a pendulum will make in a prescribed time?"
d. "Why do your answers on the post-test differ from those on your pre-test?"

The last two questions are perhaps two key points to pursue.

The Pendulum: Major Variables
Appendix
For use with
Parts 1 and 3

DIRECTIONS for TEACHER for PRE-TEST and POST-TEST

A. Prior to beginning test, teacher says: "Look I can make this weight swing. We call this a pendulum (show round trips in 15 seconds)."

B. Explain to students that they will write out answers to questions which you will illustrate with apparatus.

C. The following directions coincide with student questions:

1. Use 500 g. weight -- tie on in front of students.

2. Skip

3. Students circle best answer. Put on board -- circle all three possible answers.

4. 500 g. weight on long string. "I can hold out the pendulum this far and let it swing. I can also hold it out this far and let it swing. If I hold the pendulum out this far (larger angle) will it make more, fewer, same number of round trips in 15 seconds?"

5. "I have one weight on this string. Now I"m going to hang another weight. Will the pendulum with two weights make more, fewer, or the same number of round trips in 15 seconds?"

6. From Pre-test and Post-test question sheet.

7. "Look at this. There are two long strings, two medium strings, and two short strings. I can make all kinds of pendulums with all the weights I have here."

8. Make sure they know what you mean by "left" and "right."

9. Make sure students see apparatus.

10. From pre-test.

11. Repeat twice. Start with one weight, then two weights, then take off one weight. Then read questions.

12. Hold both weights at the same angle. "I"m going to let one go. The other I"m going to pugh."

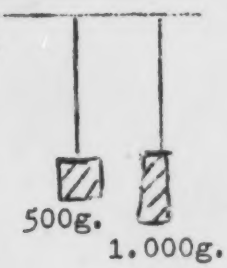
The Pendulum: Major Variables
Appendix
For use with
Parts 1 and 3

'AGRAM of PRE-TEST and POST-TEST APPARATUS

1.

2. (skip

3.



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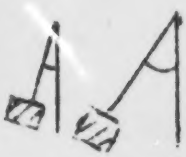

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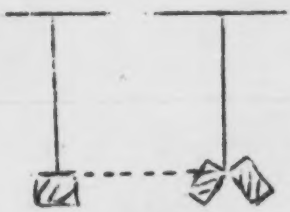

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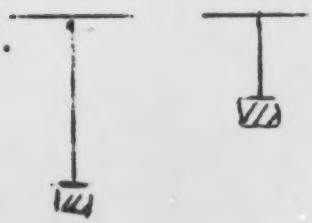

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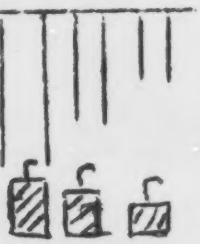

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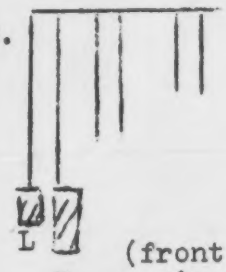
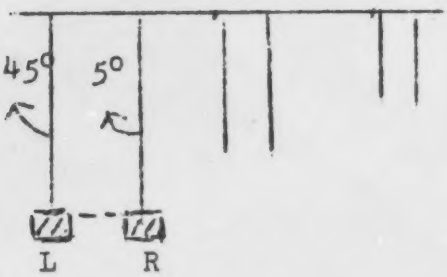


(front view)

9.



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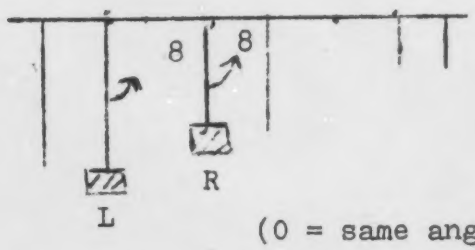
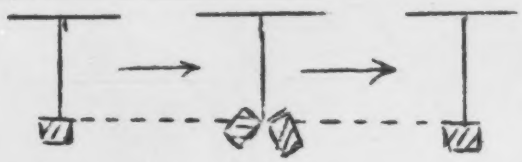


(0 = same angle)

11.



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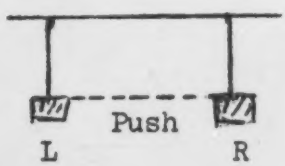


The Pendulum: Major Variables
Appendix
For use with
Parts 1 and 3

PRE-TEST and POST-TEST

Name _____

Date _____

1. You can increase the number of round trips of the pendulum in 15 seconds by... _____

_____

_____

2. (Skip)

3. The heavy weight will make (MORE), (FEWER), (SAME) number of round trips in 15 seconds because... _____

_____

_____

4. The pendulum held out further will make (MORE), (FEWER), (SAME) number of round trips in 15 seconds because... _____

_____

_____

5. The pendulum with two weights will make (MORE), (FEWER), (SAME) number of round trips in 15 seconds because... _____

_____

_____

6. The shorter pendulum will make (MORE), (FEWER), (SAME) number of round trips in 15 seconds because... _____

_____

_____

7. I would make a pendulum that makes the greatestnumber of round trips in 15 seconds by... _____

_____

_____

8. The pendulum which will make the greatest number of round trips in 15 seconds is (THE RIGHT ONE), (THE LEFT ONE), (NEITHER -- BOTH WILL MAKE SAME NUMBER) because... _____

_____

_____

(continued)

(continued)

The Pendulum: Major Variables
Appendix
For use with
Parts 1 and 3

9. The pendulum which will make the greatest number of round trips in 15 seconds is (THE RIGHT ONE), (THE LEFT ONE), (NEITHER -- BOTH WILL MAKE THE SAME NUMBER) because...___

_____

_____

10. The pendulum which will make the greatest number of round trips in 15 seconds is (THE RIGHT ONE), (THE LEFT ONE), (NEITHER -- BOTH WILL MAKE THE SAME NUMBER) because...___

_____

_____

11. The pendulum with one weight will make (MORE), (FEWER), (SAME) number of round trips in 15 seconds because...____

_____

_____

12. If you give the pendulum a push it will make (MORE), (FEWER), (SAME) number of round trips in 15 seconds because...____

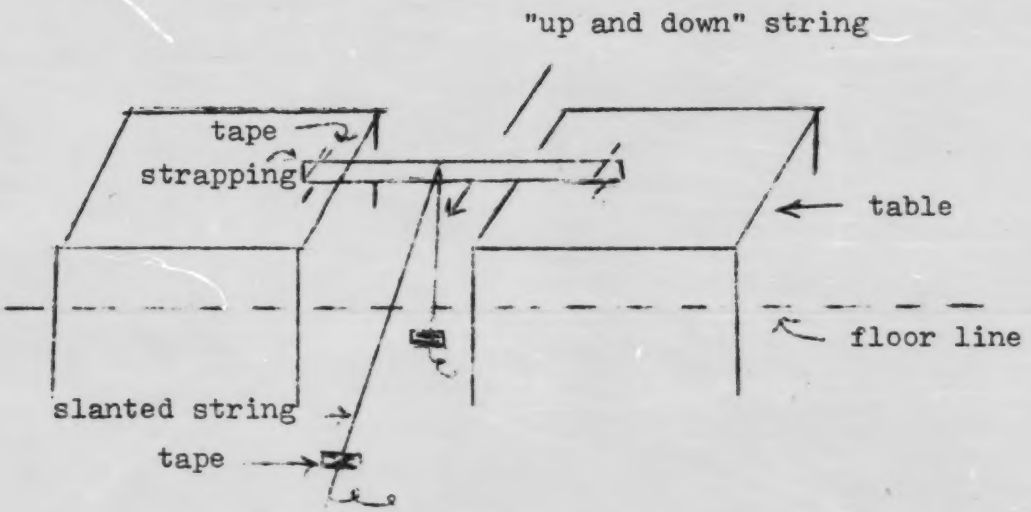
_____

_____

The Pendulum: Major Variables
Appendix
For use with
Part 2

HOW to MEASURE and FIX the ANGLE

Use a protractor here to place the string at the correct angle.



When you have the slanted string at the correct angle you can remove the "up and down" string so it will not get in the way.

The Pendulum: Major Variables
Appendix
For use with
Part 2,
(String length)

Name_____

Time	Angle	No. of Wts.	String Length	Number of Round Trips			Average (a+b+c ÷ 3)
				Trial 1	Trial 2	Trial 3	
15 seconds	10°	1	1 ½ ft.				
15	10°	1	1 ft.				
15	11°	1	6 in.				

Question: Does the change in string length cause a change in the number of round trips a pendulum will make in 15 seconds?

Answer: Yes No Not sure (Circle one)

Why did you choose the answer that you did? _____

_____

_____

_____

_____

_____

The Pendulum: Major Variables
Appendix
For use with
Part 2,
Activity 2
(Weight)

Name_____

Time	Angle	No. of Wts.	String Length	Number of Rounds Trips			Average (a+b+c ÷ 3
				Trial 1	Trial 2	Trial 3	
15 sec.	10°	1 ½ft.	1				
15 sec.	10°	1 ½ft.	2				
15 sec.	10°	1 ½ft.	3				
15 sec.	10°	1 ½ft.	Your choice				

Question: Does the change in the number of weights cause a change to occur in the number of round trips the pendulum makes in 15 seconds?

Answer: Yes No Not sure (Circle one)

Explain why you chose the answer that you did. _____

_____

_____

_____

_____

The Pendulum: Major Variables
Appendix
Part 2,
Activity 3
(Angle)

Name_____

Time	No of Wts.	String Length	Angle	Number of Round Trips			Average (a+b+c ÷ 3
				Trial 1	Trial 2	Trial 3	
15 sec.	2	3 ft.	45°				
15 sec.	2	3 ft.	20°				
15 sec.	2	3 ft.	5°				

Question: Does the change in the angle at which the pendulum is released cause any change in the number of round trips in 15 seconds?

Answer: Yes No Not sure (Circle one)

What convinced you to choose the answer that you did?

_____

_____

_____

_____

_____

_____

The Pendulum: Major Variables
Appendix
For use with
Part 2,
Activity 4
(Push)

Name _____

Time for each trial is 15 seconds.

Start Angle	No. of Wts.	String Length	What you do	Number of round Trips			Average (a+b+c ÷ 3
				Trial 1	Trial 2	Trial 3	
15°	2	1 ½ft	Let go				
15°	2	1 ½ft	Small push				
15°	2	1 ½ft	Medium push				

Question: Does the change in what you do cause a change in the number of round trips in 15 seconds?

Answer: Yes No Not sure (Circle one)

Why did you choose the answer that you did? What convinced you that you chose the right answer? _____

_____

_____

_____

_____

_____

SWINGS, SWAYS, and the PENDULUM

An Extension of the ESS Pendulums Unit

LESSON # 1: The First Explorations

Skills

Observing:

Uses observing to make predictions

Measuring:

Designs devices to measure motion of the pendulum

Controlling Variables:

1. Defines variables applicable to the problem
2. Manipulates variables to make accurate predictions

Content: Investigation Phase

Background information:

This first experience with materials is highly structured by the pendulum equipment. Children attempt to find out if pendula move back and forth at different rates. When linked with skills which are non graded the lessons on the pendulum take on a more universal quality.

Materials:

Pendulum rack or cross bars, paper clip, hooks, fishing string, # 5 1-hole rubber stoppers, sweep 2nd hand clock (optional)

Procedure:

1. Pass out equipment and help children set up equipment. See resource teacher if you have any questions and if the instructions for setting up the equipment are not in the manual or kit are not clear.

2. The number of children working together may vary from two, three, or four. One effective grouping has two pairs who work in a cluster with two sets of apparatus shared among them.

3. Suggest the task: Do pendulums move back and forth making the same number of round trips in thirty seconds? How do they account for the differences?

The Colloquium

The discussion following the experience with material sharpens perception from observations shared in the group. The teacher's role in the colloquium is to help children express thoughts clearly, to supply the right word at the right time, and most important of all to provide the psychological safety to protect the efforts of each child.

Children raise new questions which stimulate future investigations and through the support of the teacher children resolve discrepancies in observations. In the first colloquium not all children wish to participate. In later discussions when some children feel more secure they provide answers that are very insightful. The colloquium is usually initiated by asking the students to describe one observation or one action. We encourage children to limit their discussion to one contribution to encourage participation by a maximum number.

The colloquium is based on three major questions:

- What observations did you make?
- How do we solve the problem of differing results from the similar experiments?
- How do we explain the major results of the experiment?

INITIATING THE COLLOQUIUM

INSTRUCTOR: Please give us your name and then tell us about one observation that you made or one thing that you did during the session. This will give everyone an opportunity to suggest one thing that they had done.

Kristen : The string that is longer when compared to the shorter pendulum will go more slowly than the shorter string.

Laura : When the cross-piece to which the string of the pendulum is attached is loose, the pendulum will go more slowly.

Linda : If the string is shorter than the other, it will go farther.

Karen : The pendulum, that is, the bobs will tend to go longer even though the string is shorter.

Karen: If one person is holding both of the stoppers, bobs, it is much easier to get them going.

Julie: If there are five stoppers held right next to each other, they will move back and forth.

INSTRUCTOR: They go in and out?

Julie: They go in kind of a V path.

Victor : When you let the bobs go, they begin to go in a slant, but if you let them continue, their path changes and ultimately they will go straight back and forth.

Paul: If the legs of the pendulum stand which resembles a saw-horse are different distances apart on each side, the cross-bar is angled being lower on one side than the other, then the strings appear to be different lengths and the pendula tend to swing differently.

Cortell: Most of the time when I was swinging the pendulum they went from more than a minute and a half.

INSTRUCTOR: And they would stay together?

Cortell: Yes.

Mark: If you could get them to swing together you could make different patterns out of the way they swung by letting them go different ways.

INSTRUCTOR: Patterns of movement?

Mark: Yes.

(continued)

(continued) Initiating the Colloquium

Andy : When the cross-bar is slanted the pendulum tends to move in a V or inverted V.

Beth : Our bobs wouldn't work right. After 5 seconds they wouldn't be goint together.

Cheryl : It is hard to get the pendulums to go together. Most of the time it doesn't go very long. If you make the string shorter, then they tend to go together a lot longer.

Patty : Most of the time with our pendulum they would swing for about five seconds and then they would go uneven.

The instructor tends to support the discussion by intervening in the discussion rather thru intruding. An intervening question or statement tends to clarify, encourages children to construct models (explanations), stimulates new investigation, and enriches the coalescing of thinking and language into thought. At this point the teacher juxtaposes conflicting observations and encourages children to resolve these conflicts. Such a conflict is posed by instructor below:

INSTRUCTOR: Some of us were able to have our pendulums swing together for longer periods of time than others. Did anyone discover why that might happen?

Kathy: If the strings were different in length, they probably wouldn't go together. The one that is shorter tends to go faster.

Cheryl: The one with hhe longer string tends to go out farther and the one with the shorter string tends to go up higher.

Laura : The pendula functioned differently if you gave one a push and just released the other. If you start them at different times they will form different patterns of movement.

The average colloquium lasts twenty minutes in the intermediate grades. This one was limited to ten minutes because of the nature of the study of which it was a part. The final phase of the colloquium asks children to summarize the observations and understandings of the lesson.

INSTRUCTOR: Are there any other factors that can influence the way pendula swing together? If the pendulum cross-bar is slanted this seems to give different results when the pendulum is swung. Are there any statements that you think we could all agree upon?

Andy: The length of string determines how fast it does.

Mark: The legs on the pendulum stand have got to be the same distance apart.

LESSON II.: Comparing Long and Short Pendula

Skills:

Observing:

Initiates comparison of one or more variables in two equivolent independent systems.

Recording:

Uses and records repeated trials.

Controlling Variables:

Holds weight and push constant but, varies length.

Content: Investigation Phase

Background for the teacher: The second lesson defines the problem more clearly than the first exploratory lesson. By now the children should be able to set up the equipment, fill in data charts, and participate in a colloquium. In this lesson they examine the influence of all of the variables together.

Materials:

Pendulum rack or cross-bar, fish-line, one hole stoppers, protractor, ruler.

Procedure:

Sequence of the main lesson:

1. Pass out the equipment. Have children tape pendulum cross-bars between two desks.
2. Have each member of the team manipulate one of the pendula and record the results on the chart. See chart for Lesson II.
3. Have them count the number of round trips in 30 seconds.
4. Teachers often initiate the thirty second count downs as children count the number of round trips.

From ESS Pendulums text see pages 12, 13, 14.

Colloquium:

The observations in the second lesson are much more specific and refined.

Lesson II.: Colloquium

INSTRUCTOR: Remember to tell us about one observation that you made or one thing that you did in order that we might have each individual in the group make a contribution. Each time we swung our pendulum it came out the same time when we checked it for fifteen seconds.

Kathy: It doesn't matter how high you hold it up to release it, it still produces the same number of round trips in 15 seconds.

Cheryl: I don't think it makes much difference how much weight it has on it. If the weight were different but the lengths were the same and the time was the same, the number of round trips would probably be the same.

Beth: When we released our pendulum bobs for one minute, we found that they made 30 round trips in a minute and when we tried it for half a minute, it made 20 round trips.

Note: From Beth Garig's chart we discover that Beth had changed the length of the pendulum from 3 ft. 3" from which she obtained 30 round trips in one minute. She changed the length and also changed the time. She changed the length to 2 ft. 5" and for 30 seconds she had 20 round trips. This is the confusing part of her statement.

Mark: Actually the length is the only thing that makes the round trips go different. We had a different number of weights and still it didn't make a difference (in the number of round trips).

Andy: When we did it for a minute we got 30 round trips. For 30 seconds we got 15 round trips which was half and for 15 seconds we got 8 round trips which when multiplied by 4 gives 32 which is about what we got for one minute of round trips.

Eric: I have nothing to say.

Paul: I have nothing to say either.

Victor: I found out that the shorter the string, the more round trips it

taken from an unknown voice - probably one of the Kensanelly twins..for one minute the results came out the same.

Karen: (Unintelligible)

(continued)

Julie: There were more round trips when the pendulum was shorter. We made the pendulum 33'" and then compared it to 29½" pendulum. The 33½" pendulum went 31 round trips compared with the 29" pendulum going 34 round trips both in one minute.

Linda: We had a pendulum which was 36" long and when we had one weight on it, it made 31 round trips in one minute. When we added two more weights it still went 31 round trips in one minute. Therefore, we think the weight made no difference in the number of round trips.

Karen: When I did it the length was 28½". We used two weights and the number of round trips in one minute was 32 and we checked it twice and for 30 seconds we had 17 round trips and we checked it twice and for 15 seconds we had 8 round trips and we checked it twice.

INSTRUCTOR: Some people varied the length, some people varied the number of weights. One person dropped it from a greater height. We probably have to distinguish between giving it a push and dropping the bob from a greater height. Did these make any difference in the number of round trips that the pendulum made?

Cheryl: I think it would take longer if you release it from a greater height because it has to go all the way up and down again.

Eric: I think it would be just the same because it would go up higher and would have a longer distance down. I think it would be the same.

INSTRUCTOR: Paul, do you have any feeling about it? Do you have any evidence that would indicate that a greater thrust, a push, would make a difference in the number of round trips?

Andy: We tried it and it doesn't make any difference.

INSTRUCTOR: How do you feel about that, Patty?

Patty: (No response)

INSTRUCTOR: Cheryl, did you and your partner make any changes in your pendulum?

Cheryl: Yes, we shortened it a little bit. The first one we did (34" long), we did in one minute and got 30 round trips. When we did it for 30 seconds, we found that it did 20 round

(continued)

(continued) Lesson II: Colloquium

trips (incidentally the pendulum was shortened to 24½" as indicated on Cheryl's chart. Her fourth trial was also with the 24½" pendulum with two weights with 20 round trips in 30 seconds.)

INSTRUCTOR: Are there any conclusions that we might agree upon?

Julie: When the pendulum is shorter we have more round trips.

Name_____ School_____

Lesson II: Pendulum

Trials	Length of Pendulum	Number of Bobs (weights)	Number of Round Trips	Time (Minutes & Seconds)

LESSON III:

Can you set up one pendulum to make twice as many round trips as the other?

Skills:

Predicting:

Predicts the length of a pendulum making half as many trips as another.

Measuring:

Use measuring instruments more precisely

Using Numbers:

Use the ratio between lengths of long and short pendulum to increase the number of times one pendulum's periods moves

Content: Investigation Phase

Background:

In this study children attempt to establish a difference in length between the short and long pendulum such that one pendulum goes twice as fast as the other. The question then becomes: How much longer must the long pendulum be to go half as fast as the shorter one?

Materials:

Cross-bar, fish-line, # 5 one hole stoppers, rulers, clock for timing.

Procedure:

1. Have the children set up their apparatus.

2. Have children test the problem for fifteen minutes before suggesting that they limit the length of the first pendulum to two inches from swing point on the bar to middle of the pendulum.

3. Our experience with releasing pendulum indicates that best releasing is done by one person. The other partner on the other hand may hold the protractor for the correct angle of release for the pendula, and watch the clock. Partners often switch positions.

(continued)

(continued) Lesson III: Procedure

4. One partner or both may record the data. This is often neglected by some children. You should insist on completion of this task.

5. Time the number of round trips for 30 seconds.

This investigation may last for forty or fifty minutes. But, it should be stopped before the children become restless.

Lesson III: Colloquium

Task was can you make pendulum # 1 make twice as many round trips as pendulum # 2. Remember we ask each participant at first to make one and only one observation.

Kristin : If your pendulum is half as long as the other one it does not mean that the shorter pendulum will make twice as many round trips.

Julie : If you put on two pendulum bobs, it will go just as many round trips as if you put on only one pendulum bob.

Linda : . I tried to make one string twice as long as the other.

INSTRUCTOR: but she ran into some difficulty with that because the stand was not functioning properly.

Karen : We had difficulty with our stand.

Andy : If you make the short pendulum 5½ times shorter than the longer one, the results seem to be that it will go twice as fast or I mean it should be four times shorter.

Mark: . We tried it four times shorter and it still didn't work so I guess he was right about that.

Paul: . With a 16" pendulum in 30 seconds it went 20½ round trips. The number of round trips for a 32" pendulum in 30 seconds went 15 round trips so just because a pendulum string is twice as long it doesn't mean that it is going to go half as fast.

Victor: I have nothing to say. I was going to say what Paul was going to say.

Eric: I was a partner of Paul's. All the times we did it, it was either 20½ or 15 round trips. I was 4½ round trips between the two of them.

INSTRUCTOR: How long was each pendulum?

Eric: It was 16 and 32 inches long.

Laura: . We had one pendulum go twice as fast as the other. We made one long one and then we divided it by four and we made the short pendulum that length.

INSTRUCTOR: How long was the longest one?

Luara: 22" and the short one was 5½".

INSTRUCTOR: Remember when I saw your pendulum I mentioned a problem?

(continued)

(continued) Lesson III: Colloquium

Linda: It was twisted over the top of the pendulum cross-bar so that it was longer when it swung one way than when it swung the other way.

INSTRUCTOR: Do you see the problem? When the pendulum swung out one side, the top of the pendulum was the top of the cross-bar, but when it swung back through the middle the other way, the top of the pendulum was the bottom of the bar. Therefore, there was a difference between the top and the bottom of the bar which influenced the way the pendulum functioned. Does everyone understand why that is a problem?

Unknown voice: Yes, it has to come down through the middle of the bottom of the pendulum bar or you can put tape on it. If you have 22 and you divide it by four, it will give you the right answer. 16 and 4 work also.

Beth: We made one 3 ft. and the other 1 ft. and we had 25 round trips for the short one, 12 for the long one.

Cheryl: When we did it, we didn't change anything. One was 1 ft. 3" and the other was 1 ft. and there was the difference of only one round trip between the short one and the long one. The long one made 22 round trips in 30 seconds and the short one, the 1ft. one, made 23 round trips in 30 seconds.

Patty: We had the longer pendulum at 11" and when we shortened it to 9", the results on the number of round trips were the same for both lengths, that is, they both made 26 round trips.

Kathy: Our apparatus seemed to be giving us some difficulty.

INSTRUCTOR: Are there any things that you think we could agree upon this lesson?

Andy: If you divide the length of the long pendulum by four, I think that will give you the length of the shorter pendulum and it will go twice as fast as the long one. Unfortunately we didn't have enough time because we only tried it once. If you try something you have to try it a second time to be sure. The first time we tried something we got a different result than when we tried it again.

Name_____ School_____

Third Lesson Pendulum Can you make pendulum #1 make Twice as many round trips as pendulum #2?

Trial	Time min. sec.	Pendulum #1			Pendulum #2		
		Length of Pendulum	Number of bobs (weights)	Number of Round trips	Length of Pendulum	Number of bobs (weights)	Number of Round Trips

LESSON IV:

Can you set up one pendulum to make three times as many round trips as another?

Skills:

Predicting:

Confronted with a situation and a related model, suggest an expected outcome.

Content: Investigation Phase

Material:

Cross-bar or rack, fish-line, bobs, ruler, timing clock

Procedure:

1. Set up equipment as in the past.
2. Fill out data chart #4 with name, date, and school.
3. Count number of round trips in 30 seconds.
4. Children should run at least 5 trials without changing the length of the pendulum or other variables.

Colloquium:

This fourth colloquium was an extensive search for the meaning of pendulum round trip variations. The search for a concept which explained the phenomena was intense and appealing. For many reasons the search for an explanation of why one pendulum made three times as many round trips as another has a special appeal for 6th graders. Squaring the length for one pendulum to move twice as fast as another. Cubing the length of the small pendulum to determine the length of the long pendulum will produce three times as many round trips in the short one as in the long one. For children in the sixth grade this should not be a difficult task.

Lesson IV: Colloquium

The task in Lesson IV was can you make pendulum #1 make three times as many round trips as pendulum #2. As in the past I am asking you to give one and only one observation as we go around the group. I hope today we can create a conversation among ourselves in which you are talking to your neighbors. I will try to pick up or respond to conflicting ideas.

Kristin: We only had time for one observation today.

Julie : I am Kristin's partner and I didn't find any results.

Linda: We made one pendulum 7" and the other was 21". The results that we got were that the pendulum which was 7" long got 35 round trips and the one that was 21" long got 20 round trips.

Karen: Our pendulum kept on coming apart.

Karen: We performed our experiment once. One pendulum was 4" long and the other was 36". The 4" pendulum made 39 round trips, the second pendulum made 13 round trips but the second time we tried it, it didn't work.

Laura: . We made the first one 4" and the second one 24", but it didn't work. The second time we did it, we made one pendulum 4" long and the other one 36" and it seemed to come out right. The shorter one made 39 round trips and the longer one made 13 round trips.

Paul: We got it to work after three trials. We only got to try it once. We used 36" for the long one and 4½" for the shorter one. We got 14 round trips for the long pendulum and 42 round trips for the short pendulum.

Eric: : My results were the same as Paul's as we were partners.

Victor: We continued to have trouble with our stand as Paul has mentioned.

Mark : . We only got to do three trials. They really didn't come out right because they missed by 7 or so round trips.

INSTRUCTOR: Was it 7 more or 7 less?

Mark: It was 7 less round trips than it should have been.

(continued)

(continued) Lesson IV: Colloquium

We tried to get pendulum #1 as short as we could get it. It was almost at the top of the line.

Andy : Instead of dividing by 3, we tried dividing by 6. That is, dividing the length of the long pendulum by 6, because instead of dividing by 2 like we did yesterday, we divided by 4 yesterday and it worked so we thought if we doubled 3 into 6 to make 6, we thought that might work, but it didn't work.

Kathy : Ours didn't work because we couldn't make the short one short enough and we couldn't make the long one long enough.

Cheryl : If the stand isn't right, you can't really get the pendulum to work right. The first one was 5" long and it had 36 round trips and the other one, the longer one, was 3ft. and we had 15 round trips on it.

INSTRUCTOR: Some people indicated that they had some problems when the pendulum was very long.

Andy: Yes, the pendulum hit the side in a couple of our trials and we had to start over again.

Unknown voice: When our 78" pendulum made 11 round trips in 30 seconds and the shorter one made 32 round trips.

Laura : We tried to set up our pendulum for three times as many trials, but we didn't have a chance to complete it.

INSTRUCTOR: How do you make one pendulum go three times as fast as the other?

Laura : You have to multiply three times three, so it would have to be nine times longer, or nine times shorter.

Unknown voice: Well, we made the short one 2" long and we made the long one 8" long.

Karen : The 2" pendulum made 60 round trips and the 8" made 30 round trips.

Paul: We had a good rule but it didn't work. We had difficulty counting the 2" pendulum because it moved so fast.

Victor : It almost stopped after 25 seconds.

(continued)

(continued) Lesson IV: Colloquium

Eric: I was with Paul and Victor. He didn't mention the rule but I would like to mention it now. When we multiplied 3 times 2, it equals 6 which meant that we tried to make the longer pendulum 6 times as long. It didn't work.

Mark: We got to do 6 trials. In the first trial we had one 4" and the other 16". The first one we did was the smaller one was 4" long and the long one was 24" long. The 4" one made 40 round trips in 30 seconds and the 24" pendulum made 18 round trips. We tried it again and got the same results. Then we shortened the small pendulum to 2-3/4" and we changed our results. We got for the shorter pendulum we got 47 round trips and the 24" pendulum, the long one, still made 18 round trips. The second trial and the first trial we missed by 4 or 5 round trips. Our rule was the same as Eric's.

INSTRUCTOR: What was that rule?

Andy : If you want to go twice as many round trips, you made the pendulum four times as short as the long one. Making it 6 times as long and 8 times as long still didn't produce three times the number of round trips for the pendulum, for the shorter pendulum.

INSTRUCTOR: You, therefore, learned something.

Victor: In my rule I said divide instead of multiply.

Note: This lesson was interrupted by a concert being given over the school's intercom system and it resulted in a major distraction for those youngsters who were in the colloquium.

Karen : We did it and we had the short one was 2" and the long one was 8" and it did work.

Laura : . We worked together. I worked together with Karen :

Kathy : . The shorter pendulum went 36 times and that was 5" long and the long pendulum 16" long went 20 times. One short one went 32 times and the other went 6 times.

INSTRUCTOR: Well, how much more rapidly did the short one go than the long one?

(continued)

(continued) Lesson IV: Colloquium

Unknown voice: In this case divide 6 into 32.
Note: a number of answers were given. Finally it was agreed that it was around 5 so that the short one went 5 times faster than the long one.
INSTRUCTOR: Can anyone make up a rule? A rule indicates what will happen. In this case, all of the time, whenever we compared a short pendulum with a long pendulum.
Andy : To have a short pendulum go twice as fast as a long pendulum, it has to be four times as short as the long pendulum.
INSTRUCTOR: If we had a pendulum 4" long, how much longer would the long pendulum have to be to go half as fast?
Victor: You multiply 2 by itself which is 4 and then multiply 4 times the length of the short pendulum to find out what the long pendlum is.
INSTRUCTOR: When you multiply 2 by itself, what is that called?
Eric: It is called squaring.

Name_____ School_____

Fourth Lesson — Pendulum — Can you make pendulum #1 make Three-times as many round trips as pendulum #2?

Trial	Time min. sec.	Pendulum #1			Pendulum #2		
		Length of Pendulum	Number of bobs (weights)	Number of Round trips	Length of Pendulum	Number of bobs (weights)	Number of Round trips

LESSON V:

Can you make a rule in which one pendulum goes twice, three times or X times as fast as another?

Skills

Controlling variables:

1. Identifying and controlling variables influencing pendulum periods.

2. Establishes the relationship between the comparative lengths of two pendula to make A's periods X times more than B's.

Content: Investigation Phase

1. Set up apparatus as above

2. Children fill in preliminary information on the pendulum chart.

3. Children will need large pendulums hung from the ceiling or from the doorways.

Commence the lessons as in the past.

Colloquium

Many problems with use of equipment plagued some children. Precise measuring from the top of the pendulum string to the middle of the weight is important.

Lesson V: Colloquium

INSTRUCTOR: Remember please provide one observation as we go around the group.

Cheryl : We were able to make the pendulum move twice as many times, three times as many times.

INSTRUCTOR: What did you find you had to do in order to make the pendulum move twice as many times, three times as many times and you did attempt four times as many times?

Kathy : If we had tried to make it four times as many times, you would have had to make it longer, but we could only lengthen it three feet.

Kath : We were able to make it, the shorter pendulum, go twice as fast as the longer one and three times as fast as the long one, but was impossible to lengthen the longer pendulum so that we could have the smaller pendulum go four times as fast.

Julie : The first pendulum was 2" long and the second pendulum was 11-7/8" long. It worked when our rule was that we could make pendulum #1 go twice as fast as pendulum #2 because pendulum #1 went 50 round trips as a 2" pendulum and pendulum #2 which was 11-7/8" went 26 times.

Linda : We only got to do two trials. We could make it go twice as fast. When we tried to set it up to run three times as fast, we didn't have time to finish, but we knew what the rule was.

INSTRUCTOR: What do you think the rule would be for three times as fast?

Linda: To find three times as fast you multiply by 3 times 3 which is 9 and then you make the longer pendulum 9 times as long as the short one.

Karen : To make one pendulum go two times faster than the other, you made the short pendulum 2" long and the long one was 8" long. The short one we got 55 and for the long one we got 27½.

Linda : On the first trial we had the short one at 2" with which we got 50 round trips and the long pendulum at 8" and that was 30 round trips. We only had time for one trial.

(continued)

(continued) Lesson V: Colloquium

Karen : . When we did it, our 2" pendulum made 60 round trips and our 8" pendulum made 30 round trips.

Paul : We have got a good rule, but we kept trying it and trying it, but I am not sure it worked. After a couple of trials it just didn't work.

Victor: . After a couple of trials we just weren't able to make it work. We spent a lot of time fixing ours up. We had difficulty counting our 2" pendulum because it was going so fast.

Eric : . He didn't mention what our rule was. If you want to make a pendulum go three times as fast, it is 3 times 2 which is 6, which means that the longer pendulum should be 6 times as long as the shorter one.

Mark : . We did six trials. In the first wo, we had one 4" and the other 16". It worked. Our rule was the same as theirs.

Unknown voice: (Andy) If you wanted to go twice as fast you had to make the longer pendulum four times as long. For three times as fast the longer pendulum had to be six times as long. It had to be eight times as long to make it go four times as fast. It worked when the pendulum went twice as fast but it did not work with three times as fast or four times as fast.

INSTRUCTOR: That is an important discovery, isn't it?

Because of a major interruption in the program, it was necessary to return at a later time to complete the colloquium. We had completed in the first part about 4½ or 5 minutes of the session and now the last part we completed at another time.

INSTRUCTOR: How would you compare the procedure for making a pendulum go twice as fast, three times as fast, or four times faster than another pendulum?

Andy: I am not sure because we really did not have a chance to do it right, but it seems to me that you would have to multiply two times two which would be four to make the pendulum go twice as fast as the other. To make it go three times as fast as the other you have to multiply by 3 times 3.

(continued)

(continued) Lesson V: Colloquium

INSTRUCTOR: If the smaller pendulum is 2" long

Andy: to make the pendulum go four times as fast, it would have to be 1" long.

INSTRUCTOR: You didn't have a chance to test that out. How ould you compare the results that you got?

Name_____ School_____

Lesson V Pendulum Can you state a rule in which pendulum #1 makes two, three, four etc times as many round trips as pendulum #2?

Trial	Time Min. Sec.	Pendulum #1			Pendulum #2		
		Length of pendulum	Number of bobs (weights)	Number of Round trips	Length of Pendulum	Number of bobs (weights)	Number of Round trips

LESSON VI: Linking Pendulums Together

Skills:

Formulates hypothesis-
given a condition which can be repeated provides a testable explantion for repeated responses

Content: Investigation Phase

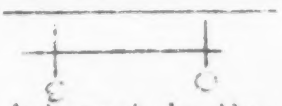
Materials:

Pendulum racks or cross-bars, hooks and string and bobs, metric rulers, elastics, straws or small 12" wooden dowels

Procedure:

1. Children use this activity to test linkages that are rigid and those that are flexiable

2. Link pendulums together with dowels in the first part of this activity. As pictured



3. After fifteen minutes if interest in the dowel links has waned, have children tie elastics to their two pendulums. It should be possible:

- to move the dowel up and down
- to determine varying responses of pendulum one and pendulum two as a result of the linkage

Colloquium:

Keeping in mind the past experience of these children in previous lessons---

How do their new observations vary in the colloquium?

How have they resolved the problem of one pendulum seeming to stand still whild the other moves?

Can they explain it in terms of energy exchange?

Does the stick or elastic when moved up or down vary the movement of owe pendulum compared to the other?

LESSON VII: Strings of Pendulums: One <u>over</u> the Other

<u>SKILLS</u>:

Interpreding data:

Bases judgement on the results of several trials

<u>Content</u>: Investigation Phase

Background:

The number of ways that pendula may be built and their complexity can only be suggested here.

<u>Materials</u>:

Pendulum bars, string, bobs, # 5 stoppers, other bobs from ESS Kit, string and hooks, masking tape

<u>Procedure</u>:

1. Link the bobs one over the other
2. Try linking long/short and heavy/light bobs
3. Twelve inch and six inch pendula heavy bobs can be suspended together in a number of ways. Can children make 16 combinations?

<u>Colloquium</u>:

How do observations vary?

How does the group resolve the discrepancies in their results.

LESSON VIII: The Pendulum and Mobiles

SKILLS

Comparing:

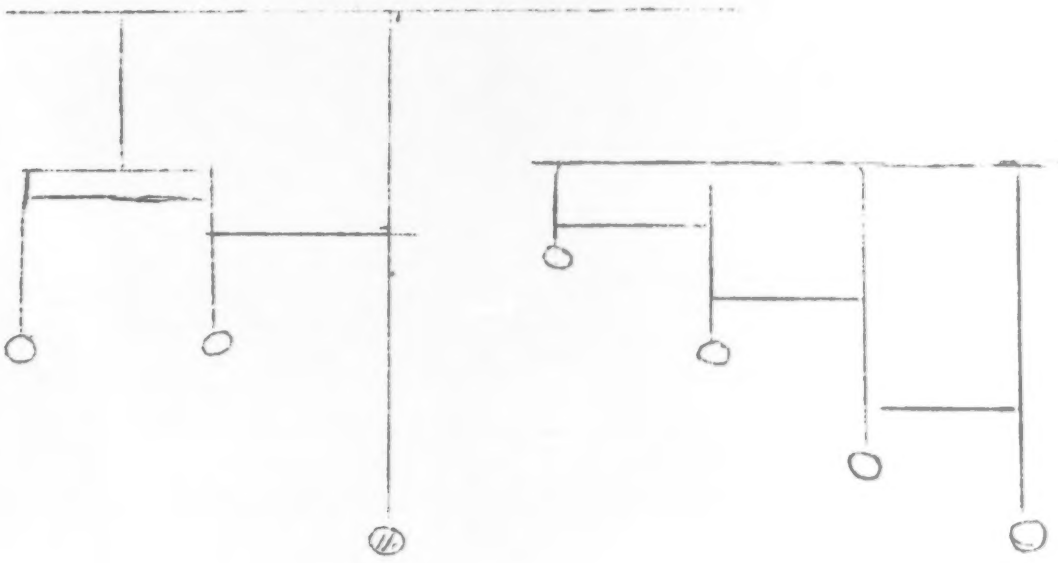
Makes comparisons between previous models and uses models to produce more complex ones

CONTENT: Investigation Phase

Materials:

racks, cross-bars, rulers, sticks, pencils, coat hangers, fishing-line, bobs of various kinds

PROCEDURE

Give the materials above. Have the children make mobiles. See ESS unit on Mobiles.

Below are examples of complex pendula